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of Engineers**

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Research Laboratories

**USACERL Technical Report 95/42  
September 1995**

# **Army Industrial Sludge Management Technologies**

## **An Evaluation and Recommendations for Improvement**

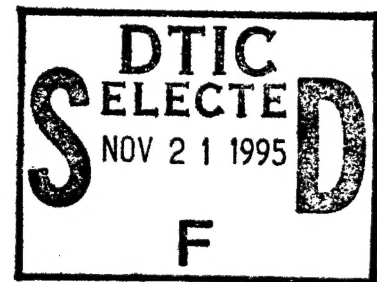
by

Byung J. Kim, Gary Hunter, Edmond Kobylinski, and Phil Martin

The industrial sludge generated by U.S. Army installations contains oil, grease, metals, and energetic compounds; and is frequently classified as hazardous waste.

Treatment of wastewater from industrial operations at Army ammunition plants, depots, and arsenals generates a large quantity of sludge that requires special handling and disposal. Treatment of the wastewater results in annual disposal costs in the millions of dollars.

The sludge management practices at four U.S. Army installations were studied to assess the current status of industrial waste treatment; to make recommendations for the improvement of current sludge management systems by applying proven technologies; and to determine future needs for research and development of treatment technologies. Technologies and management techniques that can improve the Army's current industrial sludge management include: process water reuse, electrowinning, solvent recycling, inventory control, optimal chemical use, electrochemical precipitation, membrane separation, crystallization, and dewatering. This report makes specific recommendations for each installation. Promising and future technologies needing further development include: membrane separation for various applications, recycling and reuse technologies such as regeneration of activated carbon containing energetic waste, closed loop water treatment and reuse technologies, new generation sludge thickening and dewatering technologies, and biological treatment and separation of heavy metals.



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## Foreword

This study was conducted for Headquarters, U.S. Army Corps of Engineers (HQ-USACE) under Project 4A162720D048, "Industrial Operations Pollution Control Technology"; Work Unit UZ3, "Sludge Treatment at AMC Installations." The technical monitor was Richard L. Eichholtz, SFIM-AEC-ETD.

The work was performed by the Industrial Operations Division (UL-I) of the Utilities and Industrial Operations Laboratory (EL), U.S. Army Construction Engineering Research Laboratories (USACERL). Part of the work was performed under contract by Edmund Kobylinski, Gary Hunter, and Phil Martin, of Black & Veatch, Kansas City, MO. Special appreciation is owed to the Army Materiel Command (AMC) Installations for the support to prepare this report. The following AMC Installation engineers provided technical data, reviewed this report, and provided constructive comments: Philip Darcy, Tom Pond, Dana Levy, and John Parish at Watervliet Arsenal, NY; Michael Parrent, at Tobyhanna Army Depot, PA; Tim Garret, Anniston Army Depot, AL; and Glen Parish, Kansas Army Ammunition Plant, KS. The USACERL principal investigator was Dr. Byung Kim. Ralph E. Moshage is Acting Chief, CECER-UL-I, John T. Bandy is Operations Chief, and Gary W. Schanche is Chief, CECER-UL. The USACERL technical editor was Agnes E. Dillon, Technical Resources Center.

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# 1 Introduction

## Background

The U.S. Army Construction Engineering Research Laboratories (USACERL) has been studying technological options to manage more effectively industrial sludge generated at the U.S. Army's facilities. The Army Materiel Command (AMC) is the primary generator of industrial sludge at installations such as Army ammunition plants, depots, and arsenals. AMC industrial sludge contains oil and grease, metals, and energetic compounds; as a result, it frequently is classified as hazardous waste. Because of the hazardous nature of the sludge, the Army has difficulty meeting the regulatory requirements at a reasonable cost. Although the AMC has been a leader in implementing source control measures and recycling to minimize costs, limited work has been done in using innovative sludge treatment and disposal technologies.

The U.S. Environmental Protection Agency (USEPA) estimates that there are over 13,000 generators of metal plating and finishing wastewater. Treatment of these wastewater generates an estimated 11 million metric tons of sludge (USEPA F006 waste) per year that require special handling and disposal. The generator of metal-contaminated wastewater is faced with the dual problem of removing the metal contamination from the wastewater, then disposing of the residual materials resulting from the wastewater treatment process.

Under the Resource Conservation and Recovery Act (RCRA), the Department of the Army (DA) has primary responsibility for the safe and proper disposal of waste generated at Army facilities. As a result of the types of manufacturing processes used at Army facilities, many wastewater contain low concentrations of heavy metals. Currently, the AMC's depots and arsenals that perform metal plating or metal finishing operations generate wastewater contaminated with heavy metals. Treatment of these wastewater produces large volumes of metal-contaminated sludge each year. This sludge must be handled in accordance with the RCRA, resulting in annual disposal costs in the millions of dollars.

## **Objectives**

The objectives of this study were to provide information about four AMC installations regarding current sludge management practices and future needs for research and development of treatment technologies. Both short-term solutions and long-term strategies for improved AMC sludge management using conventional and innovative treatment and disposal concepts were assessed.

## **Approach**

A literature search was conducted to examine emerging technologies for sludge treatment and disposal technologies, and to describe recommended technologies briefly. Four AMC installations were visited, and field data were collected for assessing the current status of industrial waste treatment. Based on site visits, appropriate technologies for effective sludge management were examined to develop short-term solutions and evaluate long-term needs of the facilities.

## **Scope**

This conceptual study was meant to "brainstorm" possible uses of both innovative and conventional technologies that the Army may adopt to improve industrial sludge management. Cost analyses for the proposed technologies were beyond the scope of this investigation.

## **Mode of Technology Transfer**

This study developed concepts for improving Army industrial sludge management; the concepts and technologies derived from this research will be disseminated through presentations at Army or environmental professional conferences, such as the Water Environment Federation Annual Meeting. Further development of technologies, and their field evaluations and demonstration, are recommended before implementation of the specific technology.



## 2 Wastewater Generation at AMC Facilities

Wastewater generated at AMC facilities originate from both domestic and industrial sources. Domestic wastewater can be released into the public sewer system and treated at a nearby publicly owned treatment works (POTWs) or at the facility's own sanitary wastewater treatment plant. However, industrial wastewater must be treated before release to public collection systems or on-site treatment facilities. The typical industrial wastewater and sludge from the AMC facilities are generated from depots, arsenals, and ammunition plants.

### Depots and Arsenals

The U.S. Department of Defense (DOD) authorizes different levels of military maintenance, which have been established and standardized in ascending order of complexity and cost, beginning with determination of the problem and how to correct it. Conditions determination involves complete analytical and operational inspections on-site. Repair is intended to correct failures of component parts or other known defects, but not to restore the machine to its original condition. Rebuild is the return of the machine to "like new" condition, and it involves completely dismantling and restoring the machine. Rebuild and retrofit consists of rebuilding the machine and replacing obsolete and nonsupportable units with more up-to-date units. Remanufacture involves the same processes as rebuilding and retrofitting, but it further improves the capabilities of the machine to a level beyond its original design (USEPA, October 1989).

More specifically, the three levels of maintenance defined by the DOD are:

- Organizational maintenance is usually done adjacent to the system or item being repaired. It can be done on any military base and usually can be completed by military personnel.
- Intermediate maintenance usually is not done on an operating site but is done at a nearby repair facility. Although a large percentage of this type of maintenance is performed by the military, some of it is done by private firms under contract to the military. Intermediate maintenance normally consists of calibration; repair or replacement of damaged or unserviceable parts, components, or

assemblies; the manufacture of unavailable critical parts; and technical assistance to those using and servicing the equipment.

- Depot maintenance supports organizational and intermediate maintenance by providing more extensive shop facilities, equipment, and personnel of higher technical skill than are available at lower-level maintenance facilities. Depot maintenance involves inspection, testing, repair, modification, alteration, modernization, conversion, overhauling, reclamation, or rebuilding of parts, assemblies, subassemblies, components, equipment, and weapon systems; the manufacture of unavailable critical parts; and the provision of technical assistance to intermediate maintenance organizations.

During normal operation of depots and arsenals, wastes are generated by spillage of process waste, cleaning chemicals, rinsing of cleaning chemicals from equipment, cleaning of machines used to repair or manufacture equipment, and metal finishing operations. As a result, waste streams consist of oil and grease, heavy metals, acids, and toxic organic compounds, which must be treated before they are discharged. Moreover, several metal finishing operations—including electroplating, electroless plating, cleaning, and machining—are performed at the facilities visited. Each of these activities can affect the metal content of the wastewater discharged to the treatment facility. To ensure complete collection of industrial waste from all sources, runoff from both equipment and chemical storage areas is collected in addition to the process wastes (USEPA, June 1983).

### ***Electroplating***

Electroplating consists of applying a thin surface coating of one metal upon another by electrode position. The purpose of this surface coating is to provide corrosion protection, wear or erosion resistance, antifrictional characteristics, or decoration. Common metals (ferrous or nonferrous base materials) can be electroplated with copper, nickel, chromium, brass, bronze, zinc, tin, lead, cadmium, iron, or aluminum, or combinations of these metals.

In electroplating, metal ions in acid, alkaline, or neutral solutions are reduced on cathodic surfaces, that is, on the objects being plated. The metal ions in solution usually are replenished by the dissolution of metal from anodes or small pieces of metal contained in inert wire or metal baskets. Replenishment with metal salts also is possible, especially for chromium plating. In this situation, an inert material must be selected for the anodes. Hundreds of different electroplating solutions have been adopted commercially, but only two or three types are utilized widely for each metal or alloy. For example, cyanide solutions are popular for copper, zinc, brass, cadmium, silver, and gold. However, noncyanide alkaline solutions containing pyrophosphate

have come into use recently for zinc and copper. Zinc, copper, tin, and nickel are plated with acid sulfate solutions, especially when the shapes to be plated are relatively simple. Cadmium and zinc sometimes are electroplated from neutral or slightly acidic chloride solutions. The most common methods of plating involve the use of barrels, racks, and continuously spinning spools or coils.

### ***Electroless Plating***

Electroless plating is a chemical process that depends on the catalytic reduction of a metallic ion in an aqueous solution containing a reducing agent and the subsequent deposition of metal without the use of external electrical energy. This process has found widespread use in industry because of several unique advantages over conventional electroplating. Electroless plating produces a coating of uniform thickness over the entire object regardless of its configuration or geometry. An electroless plating on a properly prepared surface is dense and virtually nonporous. Copper and nickel are the most common materials used for electroless plating. An electroless plating solution consists of the following basic ingredients:

- a source of metal, usually a salt
- a reducing agent to reduce the metal to its base state
- a complexing agent to hold the metal in solution (so it will not plate out indiscriminately)
- various buffers and other chemicals designed to maintain bath stability and to increase bath life.

The chemistry of electroless plating is best demonstrated by examining electroless nickel plating. The source of the nickel is a salt, such as nickel chloride or nickel sulfate, and the reducer is sodium hypophosphite. Several complexing agents can be used; the most common ones are citric and glycolic acids. In the presence of water, hypophosphite anions are dehydrogenated by the solid catalytic surface provided by nickel to form acid orthophosphate anions. Simultaneously, a portion of the hypophosphite anions are reduced by the active hydrogen and adsorbed on the catalytic surface, producing elemental phosphorus, water, and hydroxyl ions. Elemental phosphorus is bonded to or dissolved in the nickel, making the reaction irreversible. At the same time, hypophosphite anions are catalytically oxidized to acid orthophosphate anions, evolving gaseous hydrogen. The basic plating reactions proceed as follows:

The nickel salt is ionized in water:



There then is an oxidation-reduction reaction with nickel and sodium hypophosphite



The sodium hypophosphite also reacts in the following manner:



As can be seen in these equations, both nickel and phosphorus are produced, and the actual metal deposited is a nickel-phosphorus alloy. The phosphorus content can be varied to produce different characteristics in the nickel plate.

When electroless plating is done on a plastic material, catalyst application and acceleration steps are necessary for surface preparation. These steps are considered part of the electroless plating unit operation.

In immersion plating, a thin metal deposit is obtained by chemical displacement of the metal. Unlike electroless plating, this process is not an autocatalytic process. In immersion plating, a metal will displace from solution any other metal below it in the electromotive series of elements.

The lower (more noble) metal will be deposited from solution, and the more active metal (higher in the series) will be dissolved. A common example of immersion plating is the deposition of copper on steel from an acid copper solution. Because of the similarity of the wastes produced and the materials involved, immersion plating is considered part of the electroless plating unit operation.

### ***Cleaning***

Cleaning involves the removal of oil, grease, and dirt from the surface of the basis material using water with or without a detergent or other dispersing agent. Both alkaline cleaning (electrolytic and nonelectrolytic) and acid cleaning are included.

Alkaline cleaning is used to remove oily dirt or solid soil from work pieces. The detergent nature of the cleaning solution provides most of the cleaning action; agitation of the solution and movement of the work piece are of secondary importance. Alkaline cleaners are classified into three types: soak, spray, and electrolytic. Soak cleaners are used on easily removed soil. This type of cleaner is less efficient than spray or electrolytic cleaners. Spray cleaners combine the detergent properties of the solution with the impact force of the spray, which mechanically loosens the soil. Electrolytic cleaning produces the cleanest surface available with conventional methods of alkaline cleaning. The strong agitation of the solution by gas evolution and

oxidation-reduction reactions that occur during electrolysis enhance the effectiveness of cleaning. Also, certain dirt particles become electrically charged and are repelled from the surface. Direct current (cathodic) cleaning uses the work piece as the cathode; for reverse current (anodic) cleaning, the work piece is the anode. In periodic reverse current cleaning, the current is periodically reversed from direct current to reverse current. Periodic reverse cleaning gives improved smut removal, accelerated cleaning, and a more active surface for any subsequent finishing operation.

Acid cleaning is a process in which a solution of an inorganic (mineral) acid, organic acid, or an acid salt, in combination with a wetting agent or detergent, is used to remove oil, dirt, or oxide from metal surfaces. Acid cleaning is done with acids of various concentrations and can be referred to as pickling, acid dipping, or descaling. The solution may or may not be heated and can be used in an immersion bath as a spray. Agitation is normally required with soaking, and spraying usually is used with complex shapes. An acid dip also may follow alkaline cleaning prior to plating. Phosphoric acid mixtures commonly are used to remove oils and light rust while producing a temporary resistance to rusting. Strong acid solutions are used to remove rust and scale prior to surface finishing.

### ***Machining***

Machining is the general process of removing stock from a work piece by forcing a cutting tool through the work piece to remove some degree of the material. Machining operations such as turning, milling, drilling, boring, tapping, planing, broaching, sawing and cutoff, shaving, threading, reaming, shaping, slotting, lobbying, filing, and chamfering are included in this definition.

### **Ammunition Plants**

Ammunition plants are centers for manufacturing propellants and explosives and loading of munitions. Wastes generated during normal operations of ammunition plants include process byproducts and wastewater and spillage of propellants and explosives (often referred to as energetic compounds) and the waste streams from cleaning and rinsing of process machinery and munitions casings. Ammunition plant wastewater consist of oil and grease, heavy metals, toxic organic compounds, and energetic compounds. Runoff from chemical storage areas is collected in with the process wastewater for treatment.

### 3 Current Sludge Generation Practices

The following facilities were selected for a site visit:

- Kansas Army Ammunition Plant, Parsons, KS
- Anniston Army Depot, Anniston, AL
- Tobyhanna Army Depot, Tobyhanna, PA
- Watervliet Arsenal, Watervliet, NY.

These sites were selected because of the mission of the facility and for their locations in the United States. The purpose of these site visits was to assess current sludge generation, determine sludge disposal practices, and collect sludge disposal cost information.

#### **Kansas Army Ammunition Plant**

The Kansas Army Ammunition Plant (KAAP) occupies 13,500 acres and is located 130 miles south of Kansas City, KS, and 1 mile east of Parsons, KS (AEHA, June 1992). KAAP is a load/assemble/pack (LAP) facility that generates wastewater from explosives preparation; drying, handling, loading, and cleaning operations; and the production of detonators and lead cups at initiator production facilities.

Under the proposed National Pollutant Discharge Elimination System (NPDES) permit (Kansas Army Ammunition Plant Water Pollution Control Permit F-NE55-P004) the discharges from 11 outfall locations are regulated. Table 1 contains the proposed limits for each of these locations. Treatment systems are provided for the domestic waste and wastes generated at the 300, 900, 700, and 1100 production areas.

#### ***Domestic***

Domestic wastewater generated by the production staff is treated by the trickling filter process. The production staff indicated that the facility was currently in compliance with its NPDES permit. Biosolids generated from the sanitary facility are land-applied on site.



Table 1 (Cont'd).

Outfall #	Area	Wastewater Description	Parameters	Permit Limit (daily ave/max)	Production Based Limit (daily ave/max)	Basis for Limit
OR			TSS pH	45/85 mg/L 6-9 su		40 CFR 133.105 KS WQS KAR 26-16-28e(b)(2)(B)
004 Sewage treatment plant with connection of 700 Area's discharge	2200	Domestic Wastes + 700 Area wastewater	BOD ammonia antimony lead nitrate sulfate cyanide	See above See above 47 ug/L 29 mg/L 715 mg/L 17.5 ug/L		KS WQS KAR 28-16-28e(c)(2)(A) KS WQS KAR 28-16-28e(c)(2)(F) Fed WQS Fed WQS KS WQS KAR 28-16-28e(c)(2)(E) KS WQS KAR 28-16-28e(c)(2)(E) KS WQS KAR 28-16-28e(c)(2)(E)
008 Water treatment plant	2100	Annual Discharge of Clear Well	total residual chlorine	Nondetect		KS WQS KAR 28-16-28e(c)(2)(D)
007(a) Production Line No Connection to sewage treatment plant (Area 2200)	700	Lead Azide + RDX + Tetracene + Antimony Sulfide + Barium Nitrate + Lead Styphmate	RDX TSS O&G BOD cyanide antimony lead nitrate sulfate	0.5/1.0 mg/L 50/100 mg/L 10/15 mg/L 30/45 ug/L 200 ug/L 5 ug/L 15 ug/L 10 mg/L 250 mg/L	.07/0.21 lb/day 0.028/0.066 lb/day	BPJ BPJ & 40 CFR 457.30 BPJ & 40 CFR 457.30 BPJ & 40 CFR 457.30 KS WQS KAR 26-16-28e(c)(4) & KS GWQPS KS WQS KAR 26-16-28e(c)(4) & KS GWQPS KS WQS KAR 26-16-28e(c)(4) & KS GWQPS KS WQS KAR 26-16-28e(c)(4) & KS GWQPS KS WQS KAR 26-16-28e(c)(4) & KS GWQPS
OR						
007 Production line Connection to sewage treatment plant (Area 2200)	700	Lead Azide + RDX + Tetracene + Antimony Sulfide + Barium Nitrate + Lead Styphmate	lead	1.6 mg/L		40 CFR Par 260

Notes: FED WQS - Federal Water Quality Standards published in Federal Register, Dec. 22, 1992, p. 60911  
 KS WQS - Kansas Water Quality Standards  
 BPJ - Best Professional Judgment. Discharge limits for Boiler Location 13000 not shown.



Table 1 (Cont'd).

Outfall #	Area	Wastewater Description	Parameters	Permit Limit (daily ave/max)	Production Based Limit (daily ave/max)	Basis for Limit
009 Production Line	900	RDX + TNT + HMX	TSS (RDX + TNT usage)	50/100 mg/L	1.2/3.5 lb/day	BPJ & 40 CFR 457.30
			TSS (HMX usage)	50/100 mg/L	0.26/0.78 lb/day	BPJ & 40 CFR 457.30
			O&G (RDX + TNT usage)	10/15 mg/L	0.47/1.4 lb/day	BPJ & 40 CFR 457.30
			O&G (HMX usage)	10/15 mg/L	0.1/0.33 lb/day	BPJ & 40 CFR 457.30
			HMX + RDX TNT pH	0.5/1.0 mg/L 0.5/1.0 mg/L 6-9 su		BPJ BPJ 40 CFR 457.30
010 Production Line	10000	RDX + TNT + HMX	TSS (RDX + TNT usage)	50/100 mg/L	1.2/3.5 lb/day	BPJ & 40 CFR 457.30
			TSS (HMX usage)	50/100 mg/L	0.26/0.78 lb/day	BPJ & 40 CFR 457.30
			O&G (RDX + TNT usage)	10/15 mg/L	0.47/1.4 lb/day	BPJ & 40 CFR 457.30
			O&G (HMX usage)	10/15 mg/L	0.1/0.33 lb/day	BPJ & 40 CFR 457.30
			HMX + RDX TNT pH	0.5/1.0 mg/L 0.5/1.0 mg/L 6-9 su		BPJ BPJ 40 CFR 457.30
011 Production Line	11000	RDX + TNT + HMX	TSS (RDX + TNT usage)	50/100 mg/L	1.2/3.5 lb/day	BPJ & 40 CFR 457.30
			TSS (HMX usage)	50/100 mg/L	0.26/0.78 lb/day	BPJ & 40 CFR 457.30
			O&G (RDX + TNT usage)	10/15 mg/L	0.47/1.4 lb/day	BPJ & 40 CFR 457.30
			O&G (HMX usage)	10/15 mg/L	0.1/0.33 lb/day	BPJ & 40 CFR 457.30
			HMX + RDX TNT pH	0.5/1.0 mg/L 0.5/1.0 mg/L 6-9 su		BPJ BPJ 40 CFR 457.30
Notes: FED WQS - Federal Water Quality Standards published in Federal Register, Dec. 22, 1992, p. 60911 KS WQS - Kansas Water Quality Standards BPJ - Best Professional Judgment. Discharge limits for Boiler Location 12000 not shown.						

### **300 Production Area**

KAAP personnel indicated that 155 millimeter (mm) artillery rounds using the explosive Composition A5 are produced in the 300 production area. Because of the low volume of wastewater generated in the production line, the wastewater treatment system is operated in a batch mode at 20 gal per minute (gpm), 1 hour per day.\* Each batch of wastewater is sampled then recirculated for approximately 1.5 hours until the laboratory results are returned. If the results are within permit limits, the effluent is allowed to flow into the ditch specified in the NPDES permit. If the results are not satisfactory, which according to KAAP personnel has never been the case, the effluent is recirculated through the (diatomaceous earth filters and the GAC column) until the results meet the required limits. The low volume of wastewater produced by the 300 Line allows this flexibility.

Treatment is provided by two diatomaceous earth filters, three granular activated carbon columns, and a 100 micrometer ( $\mu\text{m}$ ) filter cartridge to catch carbon fines (Figure 1). The diatomaceous earth filters remove total suspended solids (TSS). Each filter has a 47 sq ft filtering area, a design capacity of 50 gpm, and a cake capacity of 6.9 cu ft. Only one filter is used at a time; the other one is kept in reserve until the operating filter exhibits a pressure loss of 20 lb per square inch (psi). At this point, the reserve filter is placed on line while the other is taken off line and cleaned.

The three carbon columns are operated in series. Each column has an outside diameter of 30 in., is 9 ft high, and contains 7.5 ft of carbon. Approximately 960 lb (or 30 cu ft) of Calgon 300 Filtrasorb carbon are in each column. Given a flow of 20 gpm and a carbon volume of 275 gal, the contact time in any column is 13.75 minutes. This is below the desired empty bed contact time of 20 to 40 minutes, but it is not a problem because, when operating in series, the units easily meet the NPDES permit limit of 0.5 mg/L RDX. Typical effluent concentrations for RDX have been 0.1 mg/L.

The spent carbon removed from the columns is regulated by the State of Kansas not as a hazardous waste but as a solid waste. Periodically, KAAP personnel send analytical results for between 50 and 250 drums of spent carbon to the State Department of Health and Environment. The state recognizes the spent carbon as an explosive hazardous waste K045 (40 CFR 261.32). By passing the U.S. Bureau of Mines Card Gap Test, the Detonation/Deflagration Test, the Impact Sensitivity Test, the waste is declared nonreactive and, therefore, nonhazardous. The state claims that, because the waste no longer meets the definition of hazardous waste under 40 CFR 261.3(a)(2)(iii), it can be disposed of as nonhazardous.

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\* 1 gal = 3.78 L; 1 psi = 6.89 kPa; 1 in. = 25.4 mm; 1 ft = 0.305 m.

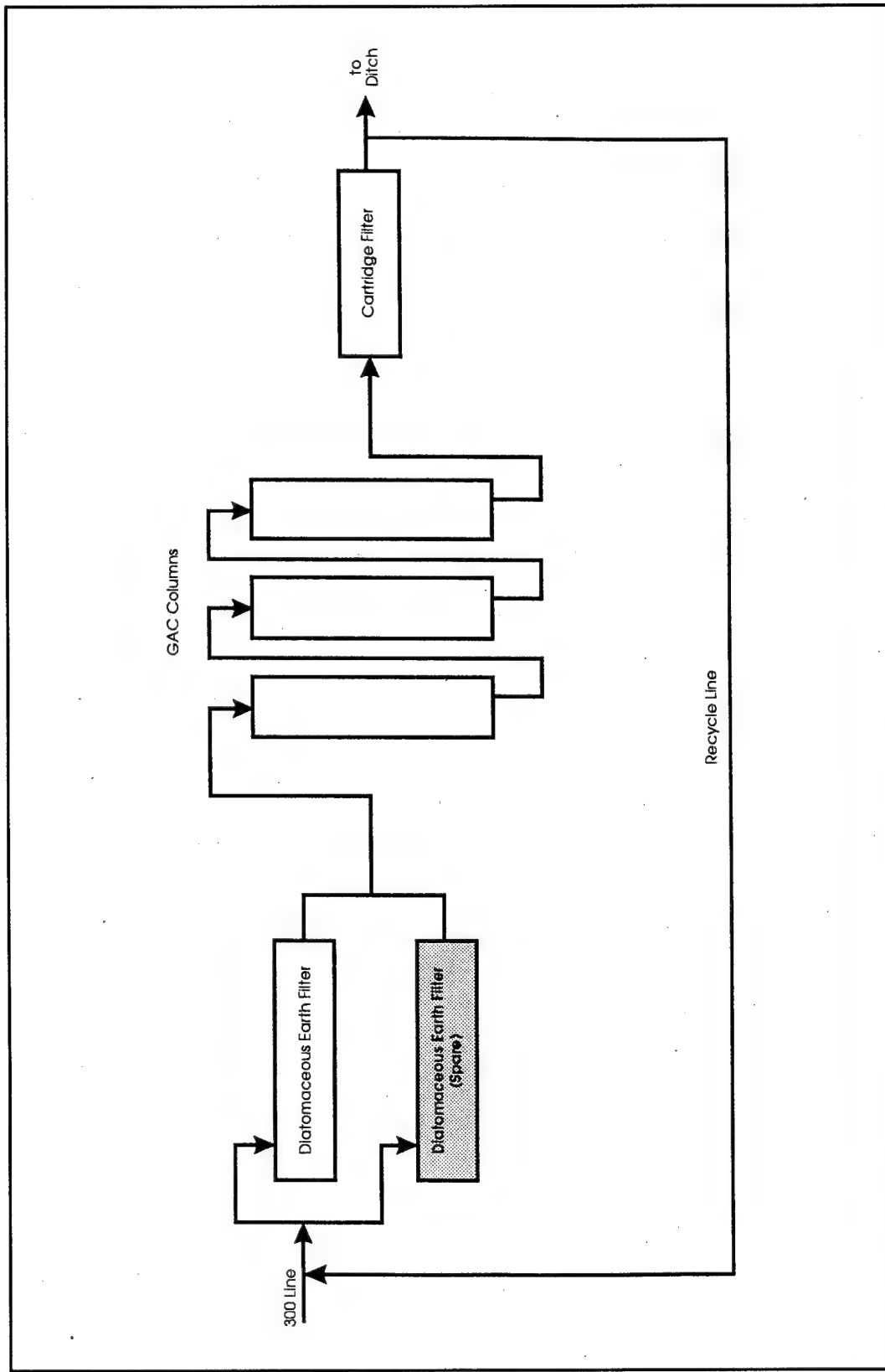


Figure 1. Wastewater treatment process schematic for building 300.

The spent carbon from KAAP's 300 and 1100 area treatment facilities has been declared nonhazardous continually as a result of this system (even though only the USEPA can declare a listed hazardous waste nonhazardous). Used carbon is sent off post for fuel blending.

### **700 Production Area**

The 700 Line produces leads, boosters, detonators, and expulsion charges using explosives such as lead azide and RDX. Wastewater produced by this line contains lead azide, RDX, lead styphnate, barium nitrate, antimony sulfide, and tetracene. This wastewater is desensitized before it arrives at the wastewater treatment facility. Desensitizing agents used are acetic acid and sodium nitrite to decompose the lead azide, sodium hydroxide to decompose RDX and lead styphnate, or steam injection to decompose tetracene. Because of the nature of the desensitizing operation, the wastewater arrives at the treatment facility with a pH of 11.

The wastewater is collected from the production area and transferred to a 12,000 gal influent holding tank equipped with a 3 horsepower (hp) radial flow mixer (Figure 2). This tank is designed for a 1.5 day surge capacity at full mobilization. When the tank contents reach 4,000 gal, a 70 gpm pump is activated and initiates the treatment process. Peak capacity is 8,000 gal per day (gpd). The wastewater flows to a 4,000-gal reactor tank designed to hold the wastewater produced in one 8-hour shift under full mobilization conditions. A 70 percent sodium hydrosulfide solution and a cationic polymer are added to precipitate lead. Provisions are available to add alum, but the system is not used because of the high pH of the wastewater. Sludge containing a lead sulfide and a small amount of lead sulfate is pumped to a 1,024-gal sludge-holding tank before being transferred to the rotary drum vacuum filter for dewatering. The vacuum filter produces a solids cake, considered a hazardous waste, which in the past has been disposed of in a hazardous waste landfill. This waste is defined in 40 CFR 261.32 as K046, a listed hazardous waste.

After leaving the reactor tank, the wastewater passes through a 1.0  $\mu\text{m}$  sock filter followed by a 0.5  $\mu\text{m}$  cartridge filter to remove solids. When a 20 psi pressure differential is detected at either of these filters, the filter is removed and replaced. The design maximum flow rate through these filters is 80 gpm. The discarded filter cartridges are considered a listed hazardous waste K046 according to 40 CFR 261.3. The filtered wastewater flows to a 4,000-gal neutralization tank where a 93 percent solution of sulfuric acid is added with the aid of a 1.5 hp radial flow mixer to lower the pH to (from 6.0 to 9.0). The tank has controlled venting to remove hydrogen sulfide. Effluent from the neutralization tank flows to the second 4,000 gal reactor tank where the remaining solids are settled out with the aid of an anionic polymer.

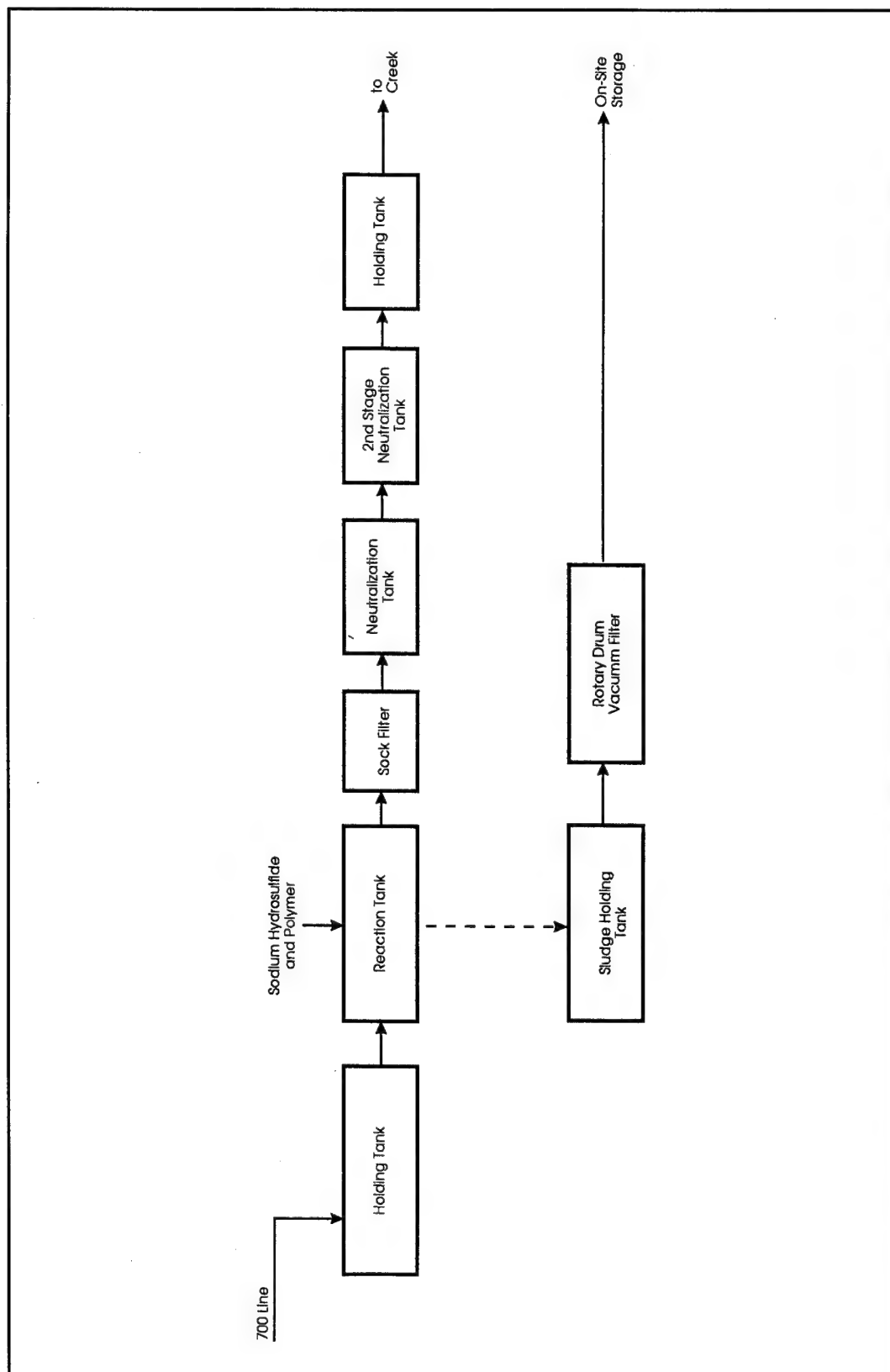


Figure 2. Wastewater treatment process schematic for production Line 700.

Alum is added only when needed. The treated effluent is pumped to a 20,000 gal holding tank, from which it is discharged to a ditch connected to Labette Creek. Alternatively, treated effluent can be discharged from the 20,000-gal holding tank through a 6-in. ductile iron pipe that is connected to the sanitary sewer.

### **900 Production Area**

The 900 Line industrial wastewater treatment system is identical in design to the 300 Line system. The 900 Line itself was not active during the site visit, but the wastewater treatment system is used occasionally. Well water from two nearby monitoring wells, rainwater from the roofs of the surrounding buildings, and paved areas surrounding the 900 Line area also drain to the treatment system.

### **1100 Production Area**

The 1100 Line, which was active at the time of the survey, produces combined effects munitions (CEM) rounds. The industrial wastewater treatment system consists of two settling basins, two multimedia filters, a clearwell, two diatomaceous earth filters, and five carbon columns (Figure 3).

One settling basin is operated while one is on standby. The basin in service is alternated weekly. The sludge, which typically contains a high concentration of cyclitol, is scraped off the bottom of the basin and either stored in an igloo or incinerated. Next in line are the multimedia filters. These filters are operated similar to the settling basins, with one filter on line and the other in reserve. Each filter has an area of 86 sq ft and a design flow of 640 to 850 gpm.\* The filter bed contains 30 in. of anthracite and 12 in. of gravel.

The filters are switched weekly, and the cake that forms on the anthracite from the used filter is scraped off manually. Facility personnel reported that this process typically results in the loss of approximately 20 bags of anthracite each week.

After the multimedia filters, the water passes into a clear well and is pumped to two diatomaceous earth filters. These filters remove TSS and are identical in design and function to those in the 300 Line treatment facility. From the diatomaceous earth filters, the effluent passes to the granular activated carbon columns. Five columns are provided, four of which are operating in two parallel trains; the remaining column is in reserve. These columns are identical in design to the columns in the 300 Line treatment system.

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\* 1 sq ft = 0.093 m<sup>2</sup>.

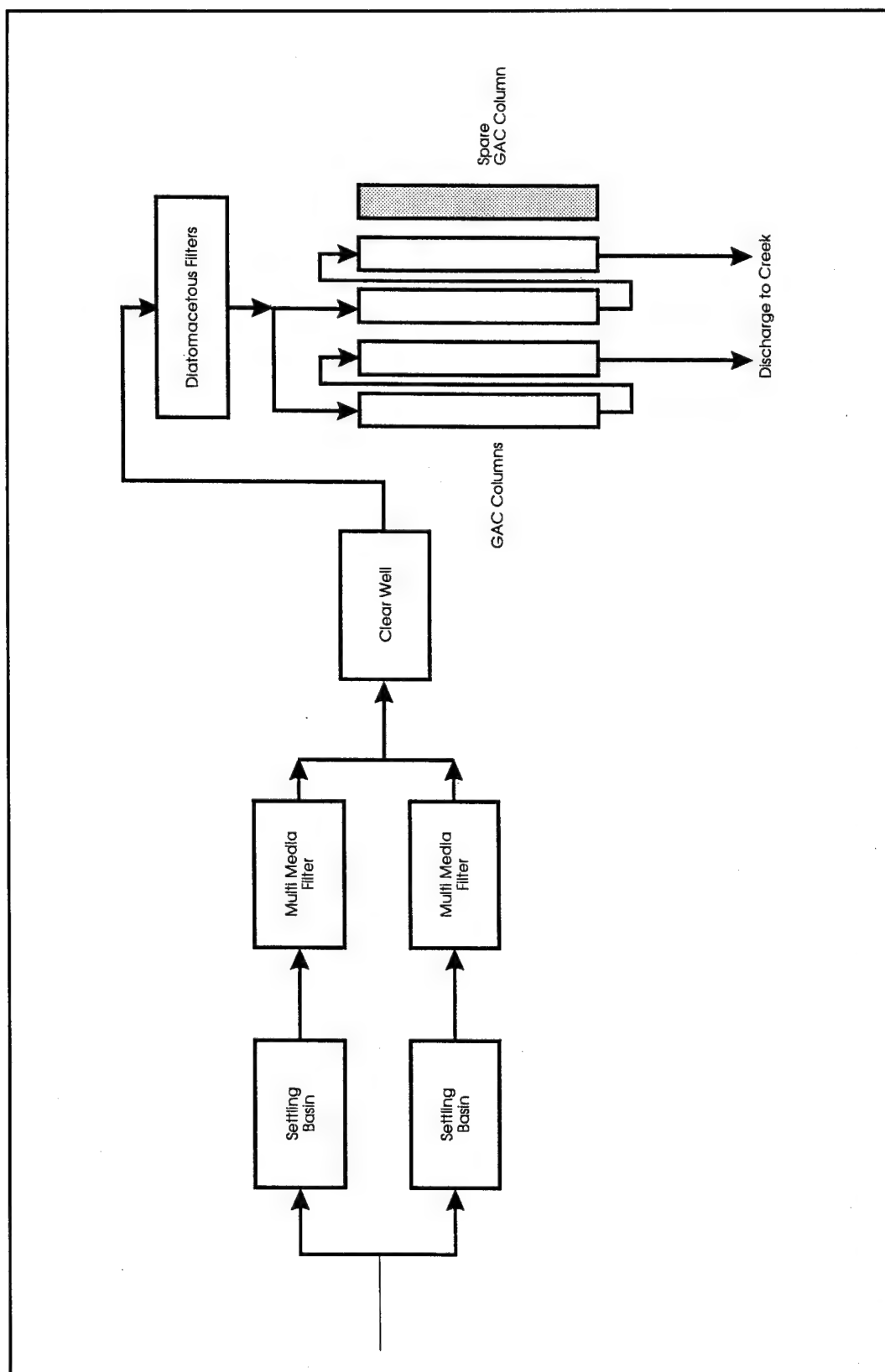


Figure 3. Wastewater treatment process schematic for production Line 1100.

## **Anniston Army Depot**

The Anniston Army Depot, AL, generates both industrial and domestic sludges. The depot's NPDES (Anniston Army Depot NPDES Permit Number AL 0002658) covers 16 discharge locations. Table 2 shows the limits for the domestic, industrial, and groundwater system. Industrial sludge generated in the cleaning and metal plating processes can be broken down into four basic waste streams: steam cleaning (Figure 4), chromium (Figure 5), cyanide (Figure 6), and general. Sludge is also generated at a separate contaminated groundwater treatment facility (Figure 7). All the treated industrial waste streams discharge to the sanitary treatment system. Sludge generated at the sanitary facility is dewatered on covered drying beds and ultimately disposed of in a landfill.

Steam cleaning wastes contain metals, oil, and grease removed from the waste stream by chemical precipitation and clarification. The sludge is dewatered on a horizontal plate and frame press, heat dried, and hauled to a nonhazardous waste landfill.

Sludge is generated from the treatment of chromium and cyanide waste streams. Two chromium waste streams require treatment. At the industrial wastewater treatment plant (IWTP), chromium is removed through precipitation and settling. The solids are pumped to a plate and frame filter press and the dewatered residue is hauled to a hazardous waste landfill. The other chromium waste stream, contaminated groundwater, is treated by an electrochemical process. The treated liquid is discharged to the sanitary treatment plant for further treatment and disposal. Sludge generated using the electrochemical process is dewatered in a plate and frame filter press and hauled to a municipal landfill for disposal. Sludge from the treatment of cyanide is pumped to a holding tank, to be subsequently dewatered by a plate and frame press and hauled to a hazardous waste landfill.

Effluent from the treated chromium and cyanide waste streams is combined with the general waste stream and treated through chemical precipitation and clarification. Sludge from the general waste stream is dewatered by a plate and frame press and hauled to a hazardous waste landfill. Effluent from the general waste stream and the steam cleaning waste effluent make up the IWTP effluent.

The IWTP effluent is combined with the domestic wastewater generated at the depot and conveyed to the East Area Treatment Plant (ESTP). At the ESTP the wastewater is treated by the extended aeration and discharged to the local receiving stream. Secondary sludge is conveyed to sludge drying beds before disposal at a local landfill. In 1992 the Anniston Army Depot spent approximately \$530,000 for the disposal of hazardous sludge and approximately \$430,000 for the disposal of nonhazardous sludge.



**Table 2. NPDES permit limits for Anniston Army Depot.**

Effluent Characteristic	Units	Discharge Limitations			Monitoring Requirements	
		Daily Minimum	Daily Maximum	Monthly Average	Measurement Frequency	Sample Type
Flow	MGD	—	Monitor	0.62	Continuous	Totalized
pH	s.u.	6.0	8.5	—	Daily	Grab
Biochemical Oxygen Demand, 5-day	mg/L	—	45.0	30.0	1/week	Composite
Total Suspended Solids (TSS)	mg/L	—	45.0	30.0	1/week	Composite
Ammonia as Nitrogen (NH <sub>3</sub> -N)	mg/L	—	15.0	10.0	1/week	Composite
Fecal Coliform (FEC)	#/100 ml	—	200	Monitor	1/week	Grab
Oil and Grease (O&G)	mg/L	—	100.0	50.0	1/week	Grab
Copper, Total (Cu, T)	ppd	—	3.33	1.67	1/week	Composite
Chromium, Total (Cr, T)	ppd	—	4.26	2.85	1/week	Composite
Iron, Total (Fe, T)	ppd	—	33.36	16.68	1/week	Composite
Lead, Total (Pb, T)	ppd	—	1.15	0.62	1/week	Composite
Nickel, Total (Ni, T)	ppd	—	2.45	1.23	1/week	Composite
Zinc, Total (Zn, T)	ppd	—	4.35	2.47	1/week	Composite
Silver, Total (Ag, T)	ppd	—	0.72	0.40	1/week	Composite
Cyanide, (A) (CN)	ppd	—	0.54	0.27	1/week	Grab
Cadmium, Total (Cd, T)	ppd	—	0.50	0.25	1/week	Composite
Chromium, Hexavalent (CR <sup>+6</sup> )	ppd	—	0.50	0.25	1/week	Composite
Chromium, Total (Cr, T)	µg/L	—	500	Monitor	1/week	Grab
Chromium, Hexavalent (CR <sup>+6</sup> )	µg/L	—	150	Monitor	1/week	Grab
Benzene (Benzene)	µg/L	—	Monitor	Monitor	1/week	Grab
Trichloroethylene (TCETHY)	µg/L	—	27	Monitor	1/week	Grab
Methylene Chloride (MTHYCL)	µg/L	—	19	Monitor	1/week	Grab
Cis & Trans-1,2-Dichloroethylene	µg/L	—	Monitor	Monitor	1/week	Grab

Note: Discharge Limitations and Monitoring Requirements. During the period beginning on the effective date of this permit and lasting through the expiration date of this permit, the permittee is authorized to discharge from the following point source(s) outfall(s), described more fully in the permittee's application: DSN001: Wastewater from East Area Wastewater Treatment System. Such discharge shall be limited and monitored by the permittee as specified here.

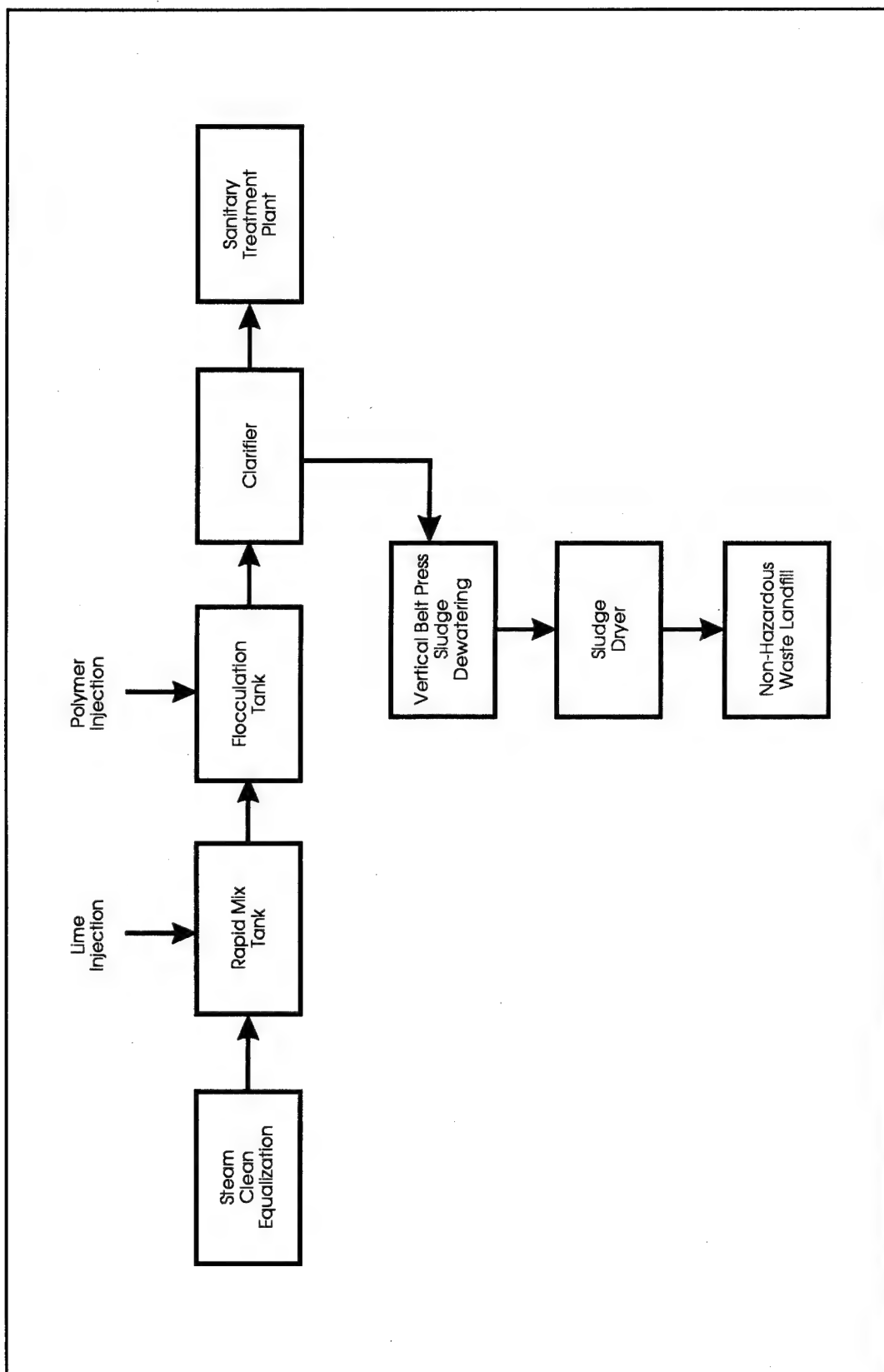


Figure 4. Steam cleaning waste treatment process schematic.

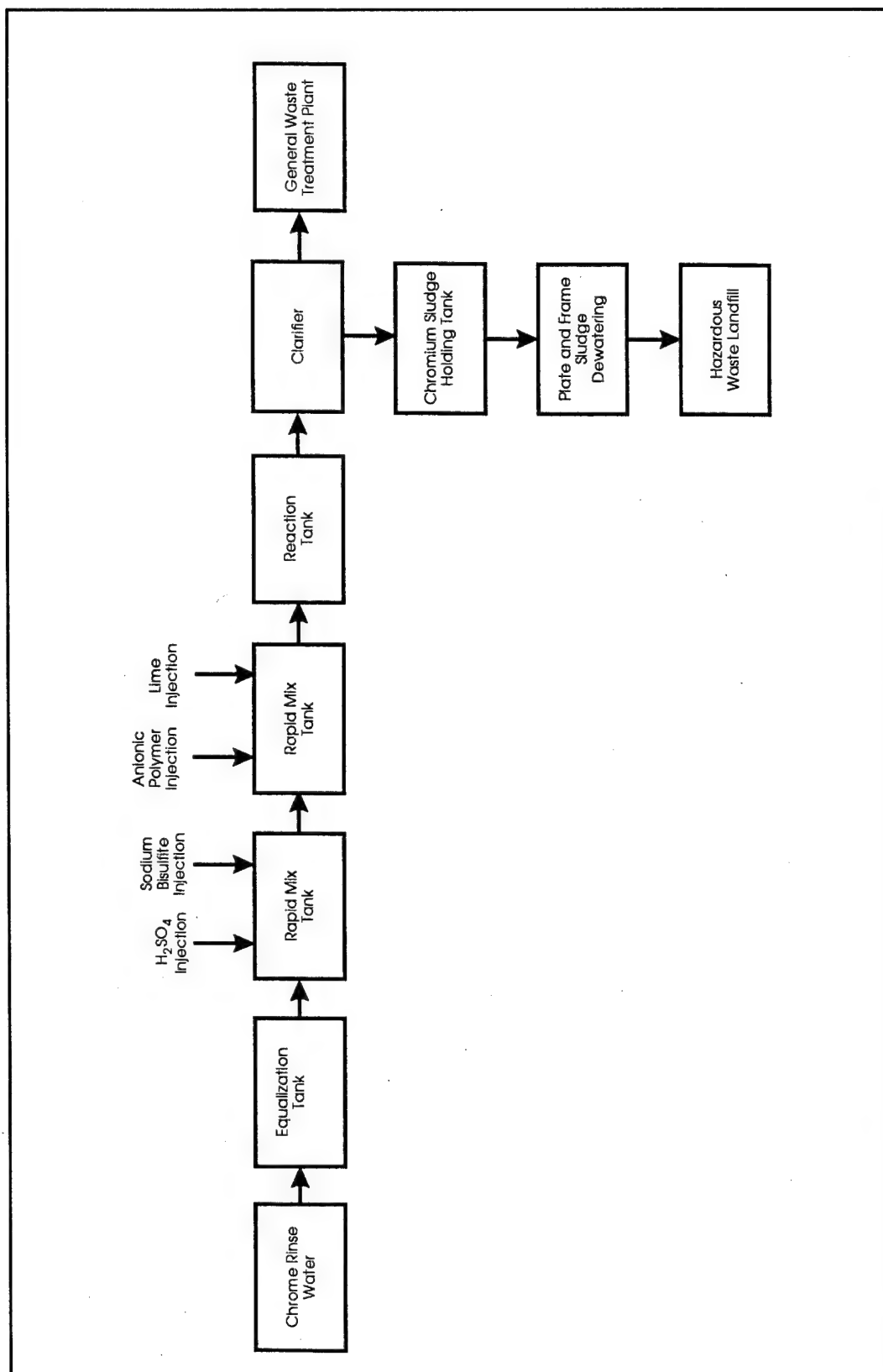


Figure 5. Industrial wastewater treatment plant chromium waste treatment process schematic.

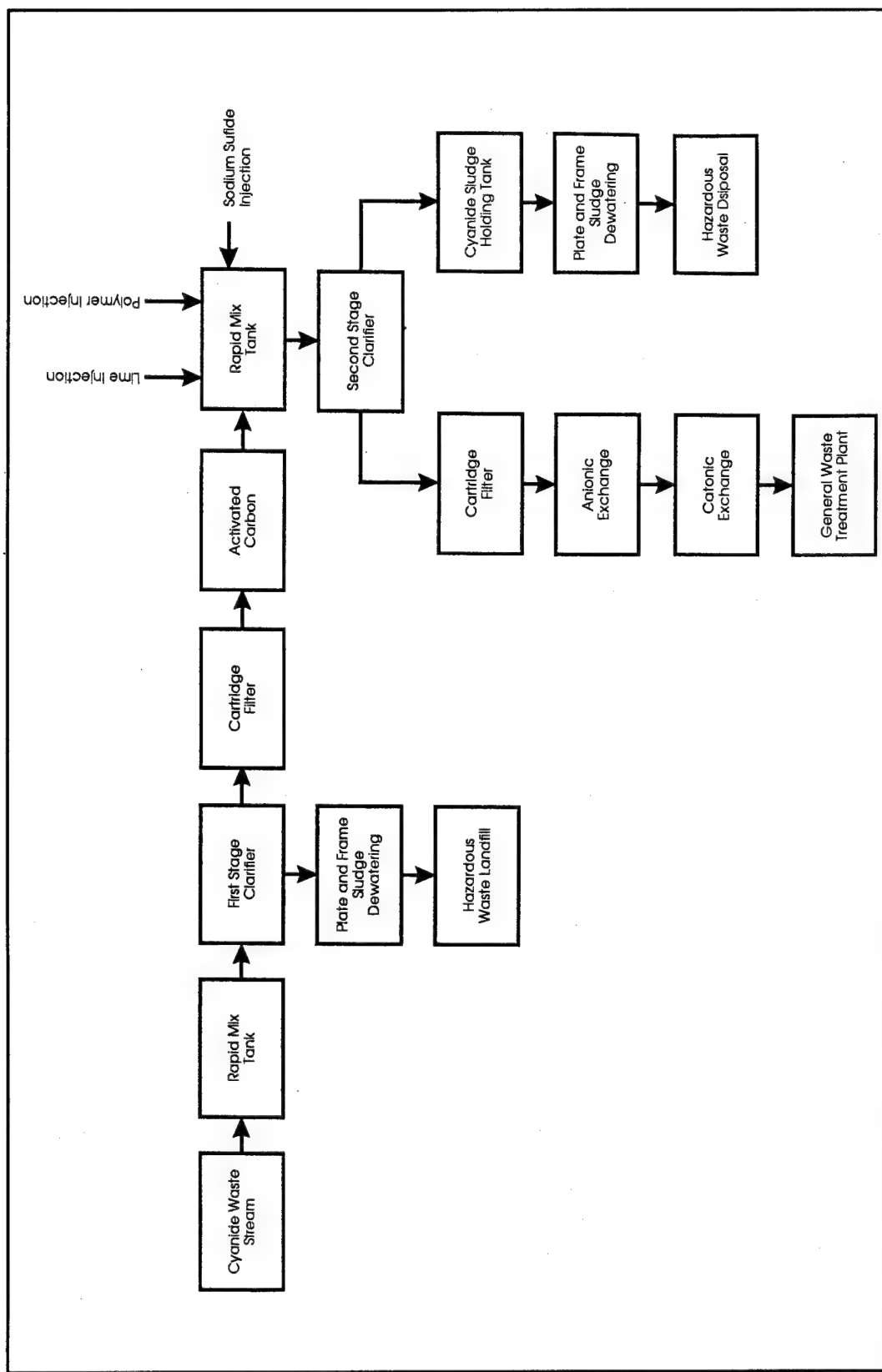


Figure 6. Cyanide treatment process schematic.

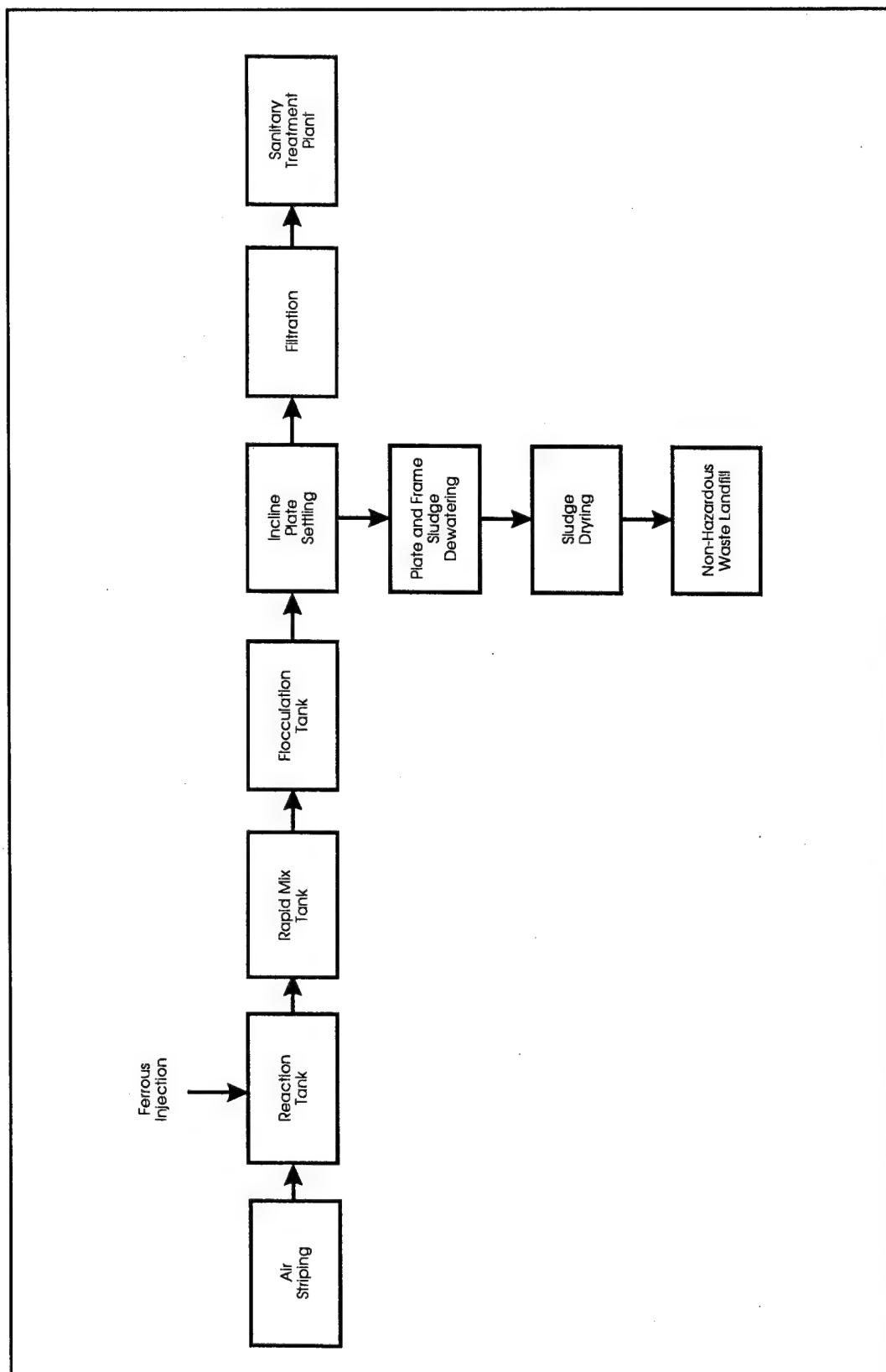


Figure 7. Process schematic Anniston Army Depot groundwater treatment system.

## **Tobyhanna Army Depot**

The Tobyhanna Army Depot, Tobyhanna, PA, generates both industrial and domestic sludge. Process schematics for the domestic and industrial plants are shown on Figures 8 and 9. NPDES permit (Tobyhanna Army Depot Wastewater Discharge Permit No. PA-0010987) limits for this facility are listed in Table 3. During 1993, the depot disposed of 99.46 tons of sludge at a cost of \$7759.89 at the Keystone landfill in Dunmore, PA.

Industrial sludge is generated in the treatment of plating and photofabrication waste streams. The IWTP has been set up to handle the following influent waste streams: rinse waters from the nickel/cadmium plating, chromium plating, and the cleaning, stripping, and miscellaneous operations from the photofabrication and plating shops as shown on Figure 10.

### ***Industrial***

The Plating Shop and the Photofabrication Shop wastewater are pretreated in the IWTP before discharge to the sanitary sewer system (Figure 9). The heavy metals from the plating wastewater are removed by the soluble sulfide precipitation (SSP) process. With the exception of chromium, which is precipitated as a hydroxide, the metals are reacted with sodium sulfide to produce highly insoluble sulfide particles. The IWTP was designed, fabricated, and installed by JRB Associates of Paramus, NJ, in 1982. An additional 20,000 gal holding tank was constructed in 1986 to store excess flow from the acid/alkali sump. At the same time, a 10,000 gal tank was added to store excess flow from the chromium sump.

Process streams from various rinse tanks in the Plating Shop are segregated into three streams: rinsewaters from the nickel/cadmium plating flow to the acid/cadmium sump; rinsewaters from the chromium plating flow to the chromium sump; and the cleaning, stripping, and miscellaneous rinsewaters from the Photofabrication and Plating Shops and the underfloor drain flow to the acid/alkali sump. The flow from the chromium sump is pumped either to the 10,000 gal tank or the chromium reduction tank at the IWTP. The hexavalent chromium is reduced to the trivalent form in the chromium reduction tank by adding sulfuric acid and sodium metabisulfite using metering pumps controlled by pH and oxidation reduction potential (ORP) controllers. After this pretreatment step, the chromium wastewater is pumped to the surge tank.

Flow from the acid/alkali sump is pumped into either one of the two 20,000 gal holding tanks at the IWTP. Acid/cadmium sump flows are pumped to a 20,000 gal holding tank. The pH is adjusted to  $8.0 \pm 0.2$  by adding caustic and mixing in the surge tank.

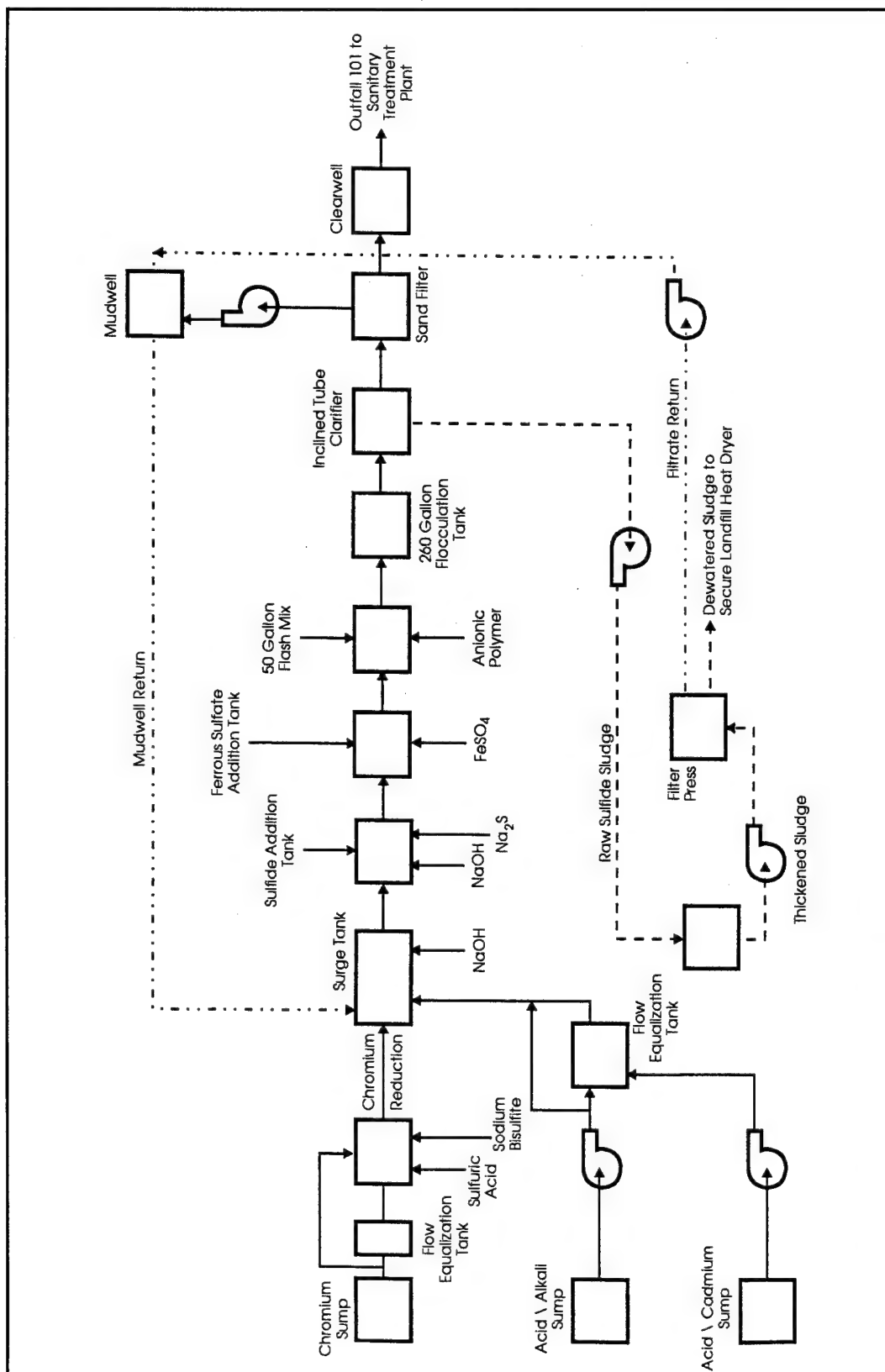


Figure 8. Industrial waste treatment schematic, Tobyhanna Army Depot.

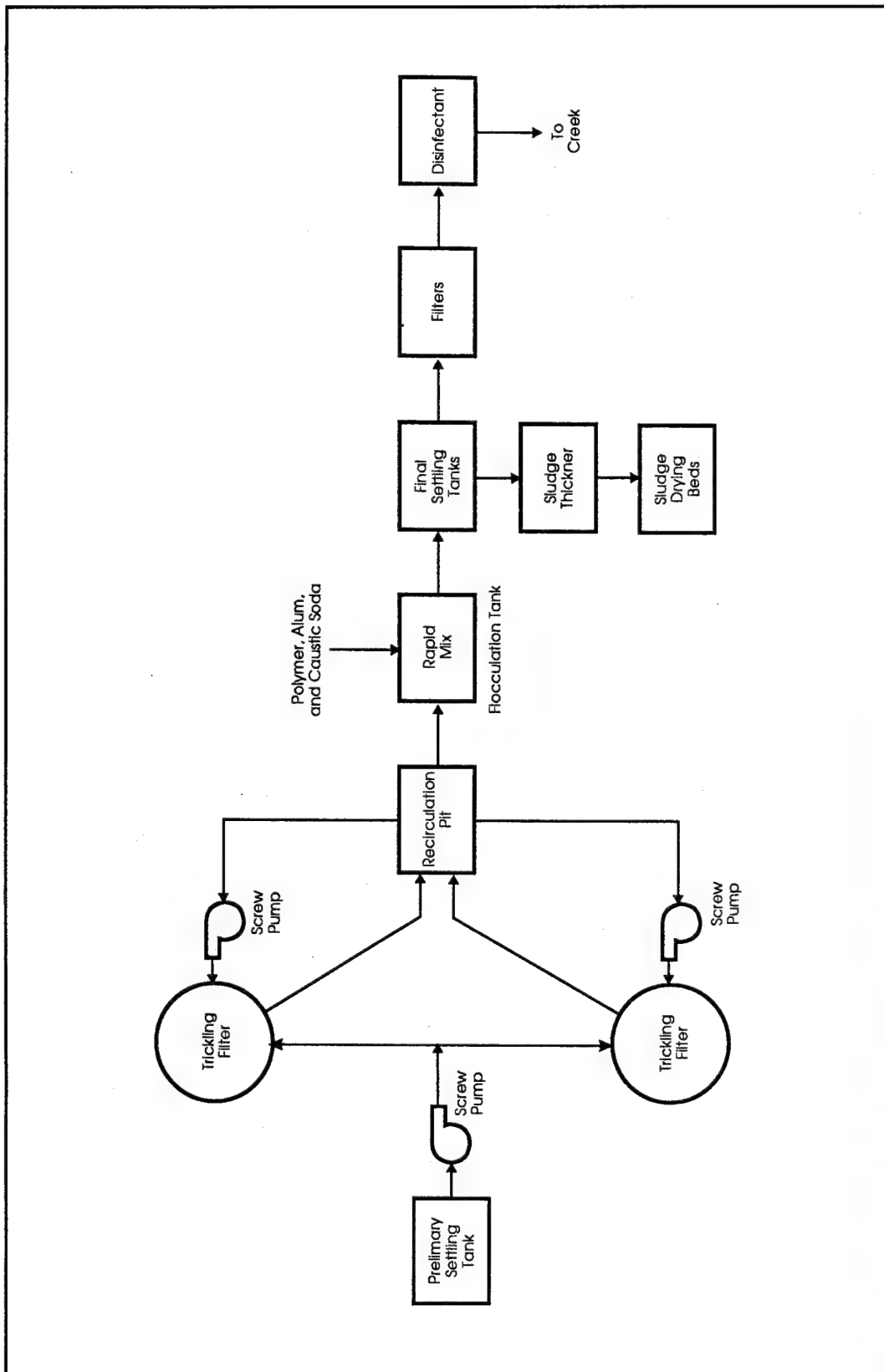


Figure 9. Sanitary waste treatment schematic, Tobyhanna Army Depot.



**Table 3. NPDES permit limits for Anniston Army Depot.**

Discharge Limitations				Monitoring Requirements					
Discharge Parameter	Mass Units (lbs/day)			Average Monthly	Concentrations (mg/L)			Sample Type	24 hr. Report Under Part A.2.D.
	Average Monthly	Average Weekly	Maximum Daily		Average Weekly	Maximum Daily	Inst. Maximum		
Flow (mgd)	XXX	XXX	XXX	XXX	XXX	XXX	XXX	Recording Instrumentation	
CBOD <sub>5</sub>	167			25.0			50.0	1/Week	8-hr. composite
Total Suspended Solids									
Solids	200			30.0			60.0	1/Week	8-hr. composite
NH <sub>3</sub> -N (5-1 to 10-31)	13.4			2.0			4.0	1/Week	8-hr. composite
NH <sub>3</sub> -N (11-1 to 4-30)	40.2			6.0			12.0	1/Week	8-hr. composite
Phosphorus as "P"	6.7			1.0			2.0	1/Week	8-hr. composite
NO <sub>2</sub> plus NO <sub>3</sub> -N	66.9			10.0			20.0	1/Week	8-hr. composite
Dissolved Oxygen	Minimum of 7.0 mg/l at all times							1/Week	Grab
Chlorine Residual				Monitor Only				Daily	Grab
Total Cadmium*				Monitor Only				1/Month	8-hr. composite
Hexavalent Chromium*				Monitor Only				1/Month	8-hr. composite
Total Copper*				Monitor Only				1/Month	8-hr. composite
Total Lead*				Monitor Only				1/Month	8-hr. composite
Total Nickel*				Monitor Only				1/Month	8-hr. composite
Total Silver*				Monitor Only				1/Month	8-hr. composite
Total Zinc*				Monitor Only				1/Month	8-hr. composite
Free Cyanide*				Monitor Only				1/Month	8-hr. composite
Total Phenols*				Monitor Only				1/Month	8-hr. composite
Chloroform*				Monitor Only				1/Month	8-hr. composite**
pH				Within the limits of 6.0 to 9.0 Standard Units at All Times				Daily	Grab

Excess coliform - Oct 1 thru April 20. See other requirements Part C - 2 000/100 ml as a geometric average. 1/week Grab May 1 thru Sept. 30 See Footnote (2) - 200/100 mL as a geometric average. 1/week Grab

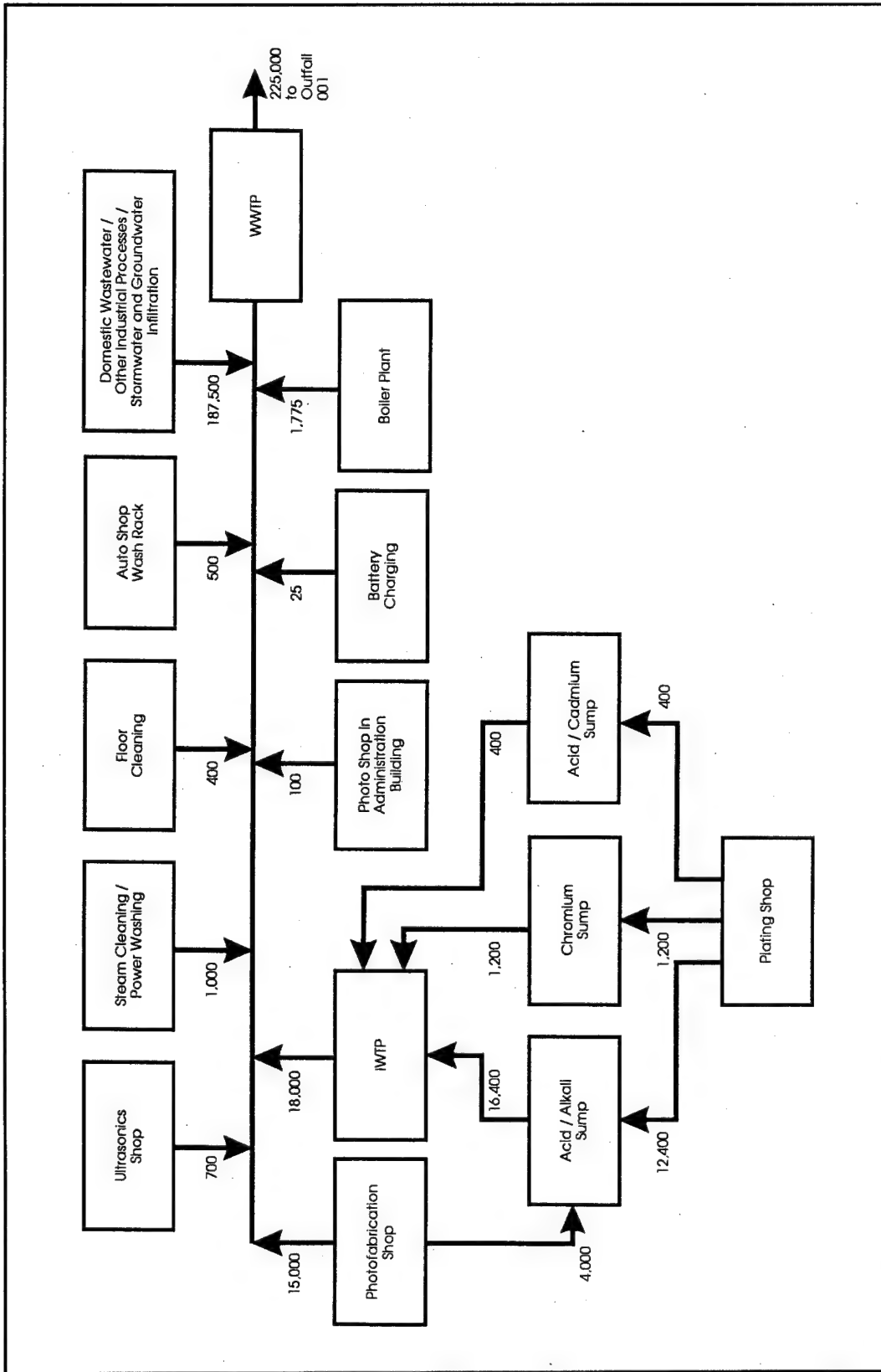


Figure 10. Wastewater balance, Tobyhanna Army Depot.

The plant has only limited ability to control the pH because it uses only a caustic solution; therefore, when the pH of the incoming stream is higher than 8, the postreduction chromium wastewater (pH in the range of 2 to 3) is pumped into the surge tank to reduce the pH ahead of the sulfide addition tank. This method of pH control is effective only when flow from the chromium plating operations is large.

The pH adjusted stream is pumped from the surge tank to the sulfide addition tank. Sodium sulfide is dosed by a metering pump when the sulfide ion probe senses a sulfide concentration below 1 mg/L. Caustic is added as necessary to maintain the pH at  $8.0 \pm 0.2$ .

The effluent from the sulfide addition tank overflows into the ferrous sulfate tank to precipitate the unused sulfide as iron sulfide and to promote flocculation. The effluent from the ferrous sulfate addition tank overflows into the flocculation tank where an anionic polymer (Cyanamid Magnifloc 1820-A) is added. The polymer addition tank overflows to the flocculation tank.

The floc formed in the flocculation tank overflows to an inclined tube clarifier. The clarifier underflow is pumped to a gravity thickener. The thickened sludge is pumped to a plate and frame filter press. The dewatered sludge from the filter press is removed weekly, run through a sludge dryer, and disposed of off-site as a hazardous waste. Effluent from the clarifier passes through a sand filter before it is discharged through a clear well to the sanitary sewer leading to the wastewater treatment plant (WWTP).

Routine maintenance at the IWTP includes replacement of the filter sand and calibration of probes. The filter sand is replaced annually or when backwashing becomes excessive (four or more backwash cycles per 8-hour operating day). The filter sand and metal sulfide fines are disposed of off-site as hazardous waste. The pH, ORP, and sulfide probes are serviced and calibrated by a contractor every 6 months.

### **Domestic**

The WWTP is an advanced wastewater treatment facility utilizing the trickling filter process for 5-day biochemical oxygen demand ( $BOD_5$ ) and ammonia removal and for an alum system for phosphorus removal. The plant is designed to treat an average daily flow of 0.8 million gal per day (mgd) and a peak flow of 1.69 mgd. The actual flow ranges from 0.2 to 0.3 mgd on workdays and from 0.06 to 0.1 mgd during the weekend. Based on daily operating logs for the period from January 1991 to September 1992, the mean flow was approximately 225,000 gpd, with a maximum flow of 624,000 gpd and a minimum flow of 73,000 gpd.

Influent wastewater flows through a bar screen and a Parshall flume to the primary settling tanks, which are equipped with manually operated slotted pipes to remove scum and motor driven conveyors for collecting sludge. The scum flows by gravity to the sludge digester pumps and is pumped to the primary sludge digester.

The effluent from the primary settling tanks flows by gravity to the screw pump pit and is conveyed by two screw pumps to the trickling filters. Although the plant is configured as two parallel trains, only one trickling filter is operated because of low organic loads. Recirculation to the trickling filters is used by positioning of the gates in the recirculation pit.

The effluent from the recirculation pit flows by gravity to the flash mix tank where alum is added to remove phosphorus and polymer is added to enhance precipitation of solids. The wastewater next flows to the flocculation tank where the mixture is gently agitated to promote floc formation and caustic soda is added for pH adjustment.

Effluent from the flocculation tank flows to the final settling tanks. The sludge flows by gravity to the sludge thickener, and effluent flows to the sand filters. The sand-filtered effluent is disinfected with chlorine and discharged into Hummler Run.

The Tobyhanna facility has conducted pollution prevention/waste minimization practices for some time. An on-site evaluation of various wastewater treatment processes was conducted, and wastewater volume reduction was recognized as a key to minimizing treatment costs, regardless of the treatment process used. Several techniques were recommended, including multiple-stage rinsing, spray rinsing, rinsewater reuse, conductivity control, dragout recovery, and dragout minimization. By implementing these techniques, the wastewater flow generated in the plating shop and printed circuit board areas during normal working hours was reduced from 200 gpm to 30 gpm.

In 1993, the Tobyhanna Army Depot won environmental stewardship awards from the AMC and the DA for several ongoing activities, including the following:

- development of a written hazardous communications program
- employee training for better understanding on how to handle hazardous materials
- review and approval process for every piece of equipment that potentially can pollute the air and water
- automation of both the industrial waste and sewage treatment plants
- received a \$37,000 recycle tonnage credit, which was turned over to a local township.

Many of these reductions are based on pollution prevention/waste minimization activities. One such activity was the installation of an electrowinning system in the plating area. However, operation of this system has been difficult because the equipment has not functioned as designed. The depot is investigating procedures to make the system operational.

The depot is also evaluating processes to maintain compliance with its NPDES permit. The 1987 amendments to the Clean Water Act required the control of toxic pollutants in water bodies and led to a fundamental shift in the development of NPDES permit limits. In the past, the best available technology (BAT) was used as the basis for determining allowable discharges of pollutants. Permit limits are currently established on the basis of water quality standards; as of May 1995, the USEPA has proposed its *Effluent Guidelines—Metal Products and Machining (MP&M), Phase 1*. In other words, permit limits are such that in-stream water quality will not be violated.

Implementation of water quality-based permit limits begins with data collection. At some point in time, other military installations' NPDES permits may require monitoring the IWTP or WWTP effluent for certain constituents. In the past, the data from such monitoring were not always used to develop permit limits; however, this has now changed. Under the current program, monitoring data will become the basis for future numerical limits. Because the permittee collects the data, the permittee has indirect responsibility for future numerical limits in the installation's NPDES permit.

Each military installation permit holder should consider the development of a formal quality assurance/quality control (QA/QC) plan, if one does not exist. The QA/QC plan will define all sample collection procedures, proper sample preservation methods, chain of custody documentation, and analytical QC procedures. Because the in-stream water quality standards are in the microgram per liter range and are at or near analytical detection limits, analytical error can have a large impact on the analytical results. Therefore, it is critical for military installations to ensure that samples are not contaminated during collection, while being transported, or during analysis. The USEPA has published guidance for clean sampling techniques (EPA, 1993). Duplicate samples, trip blanks, and spiked samples will need to be collected, in addition to the standard QC samples used by the laboratory to verify the reliability and accuracy of the analytical data. Probably the best approach for a permittee is to treat monitoring requirements as if they were numerical limits. Improper sampling and analysis techniques will produce poor data. Poor data will result in stricter permit limits.

Currently, the Tobyhanna Army Depot is struggling to stay in compliance with cadmium, copper, lead, and zinc limits and is investigating the options listed here. The

difficulty in meeting the effluent discharge limits is that the NPDES permit limits are established at or very near the water quality standard. These low discharge limits have been established because the receiving stream into which the depot discharges is a drinking water source for a downstream community.

## **Watervliet Arsenal**

The Watervliet Arsenal, Watervliet, NY, generates industrial sludge from the treatment of acid, cyanide, and oil wastes. Unlike the Army facilities discussed previously, no domestic sludge is generated because domestic wastewater is discharged to the local POTWS. The NPDES permit (Watervliet Arsenal, SPDES and Air Permit, SPDES NY-0023361) limits (Table 4) apply only to industrial discharges.

At the arsenal's IWTP, acid waste, which may contain heavy metals such as chromium, is treated chemically to reduce hexavalent chromium to trivalent chromium, and by precipitation (Figure 11). Alum is added as a coagulation aid. Sludge produced by this treatment accumulates in the clarifier and flows to sludge drying beds. Fluid captured from the sludge drying beds is returned to the head of the treatment plant, and the dried sludge is picked up by a contractor and disposed of in an hazardous waste landfill.

The remaining waste streams, oil, and cyanide are kept segregated and partially treated before being combined with the acid waste stream. Oil wastes are treated by adding alum under quiescent conditions to facilitate separation of free oil, soluble oil, and solids. The sludge generated during oil separation is pumped directly to the sludge drying beds (Figure 12). The free oil is skimmed off the top and removed by a contractor; the waste stream containing soluble oil is combined with the acid waste stream for treatment. Cyanide waste is treated to convert cyanide to cyanate before being combined with the raw acid waste stream for treatment (Figure 13). As a result, sludge is generated during the final stages of raw acid waste treatment rather than during cyanide waste treatment.

Table 4. Watervliet SDES permit.

91-20-2a (1/89)

SPDES NO.: NY 002 3361

Part 1, Page 2 of 5

Modified 1/24/92

## FINAL EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

During the period beginning EDM  
 and lasting until January 1, 1994  
 the discharges from the permitted facility shall be limited and monitored by the permittee as specified below:

Outfall Number & Effluent Parameter	Discharge Limitations			Minimum Monitoring Requirements	
	Daily Avg	Daily Max	Units	Measurement Frequency	Sample Type
002-Process	NA	Monitor	gpd	Continuous	Recorder
Flow	NA	6	lbs/day	Monthly	Composite
Barium, Total	NA	0.6	lbs/day	Monthly	Composite
Cadmium, Total	NA	3	lbs/day	Monthly	Composite
Chromium, Total	NA	0.3	lbs/day	Monthly	Composite
Chromium, Hexavalent	NA	1.9	lbs/day	Monthly	Composite
Copper, Total	NA	3	lbs/day	Monthly	Composite
Cyanide, Total	NA	1.2	lbs/day	Monthly	Composite
Nickel, Total	NA	3	lbs/day	Monthly	Composite
Zinc, Total	NA	0.04 2	lbs/day	Monthly	Composite
Solids, Total Suspended	NA	29.2	lbs/day	Monthly	Composite
Oil & Grease	NA	15	mg/L	Monthly	Grab
pH (Range)	6.0-9.0		su	Monthly	Grab
Manganese	NA	0.03 2	lbs/day	Monthly	Composite

003-Storm runoff

No monitoring required. No industrial wastes, other than the treated effluent from 002, shall be allowed.

004-Cooling Water & Storm Runoff

Flow	NA	Monitor	gpd	Continuous	Recorded
Iron, Total	NA	.7	lbs/day	Monthly	Grab
Solids, Total Suspended	NA	5.4	lbs/day	Monthly	Grab
Oil & Grease	NA	15	mg/L	Monthly	Grab
Temperature	NA	90	°F	Monthly	Grab
pH (Range)	6.0-9.0		su	Monthly	Grab

006, 007, 008, 009 - Storm Runoff

No monitoring required. No industrial wastes shall be allowed

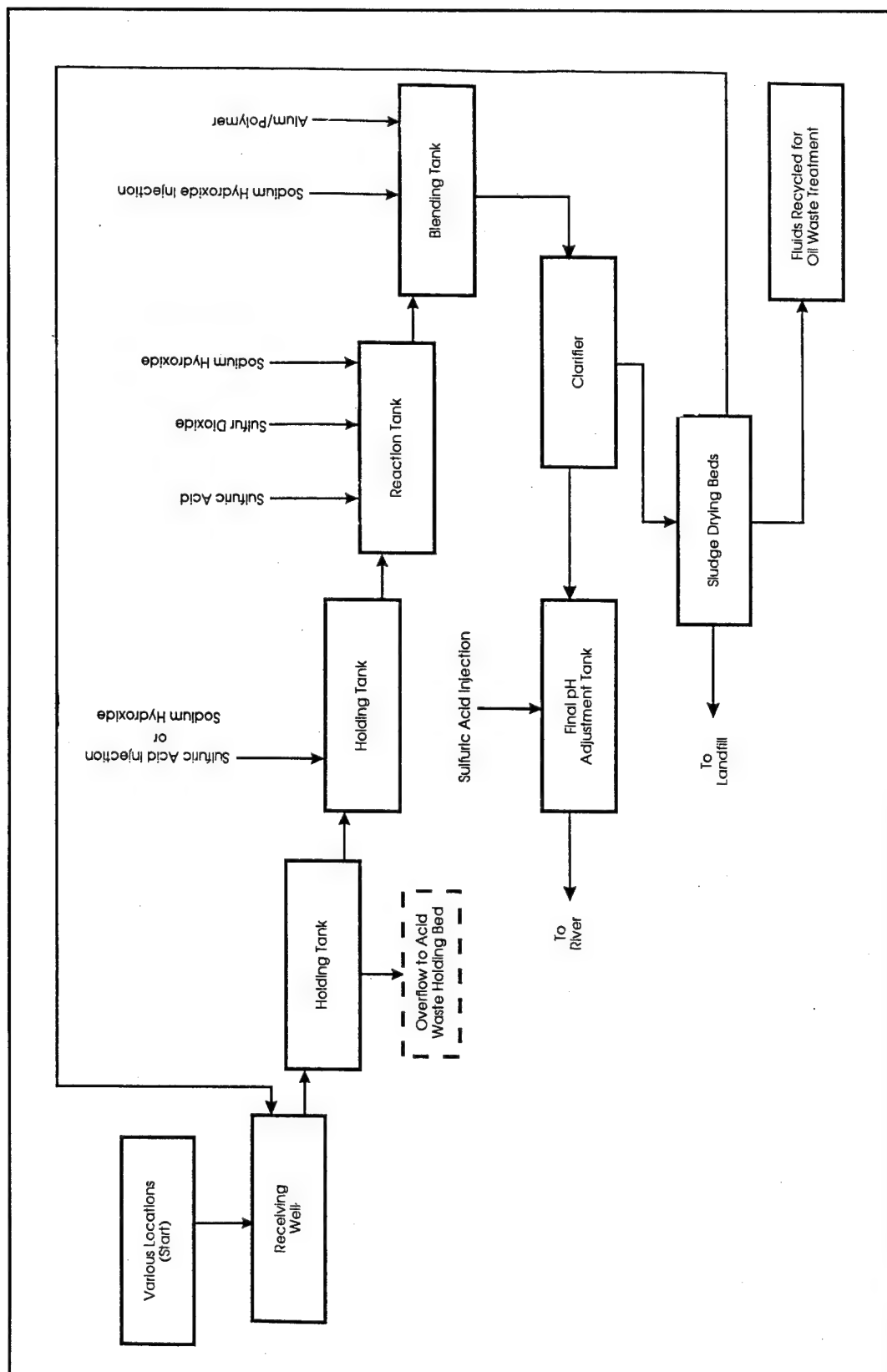


Figure 11. Chromium treatment schematic, Watervliet Arsenal.



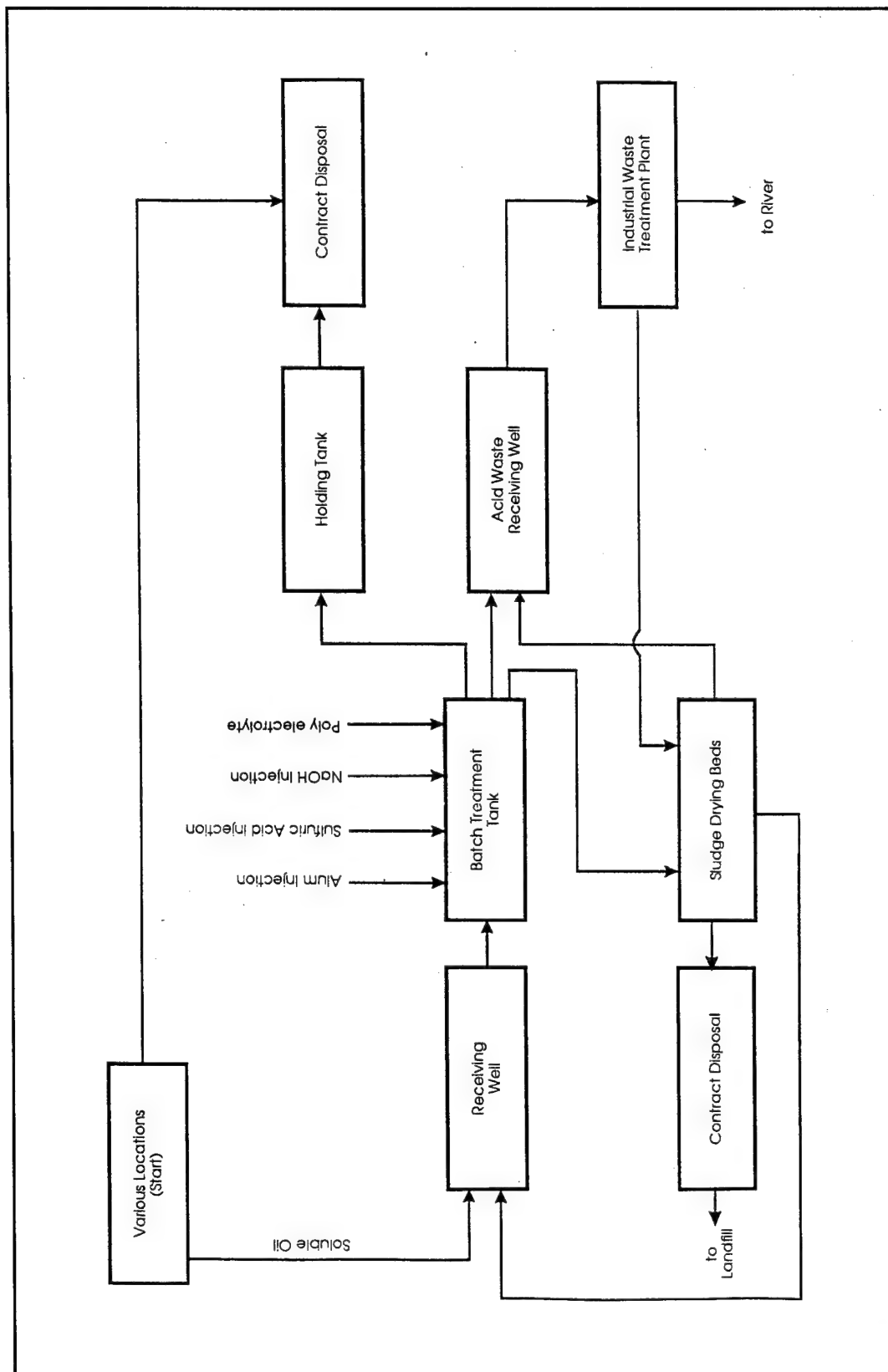


Figure 12. Oil and grease treatment schematic, Watervliet Arsenal.

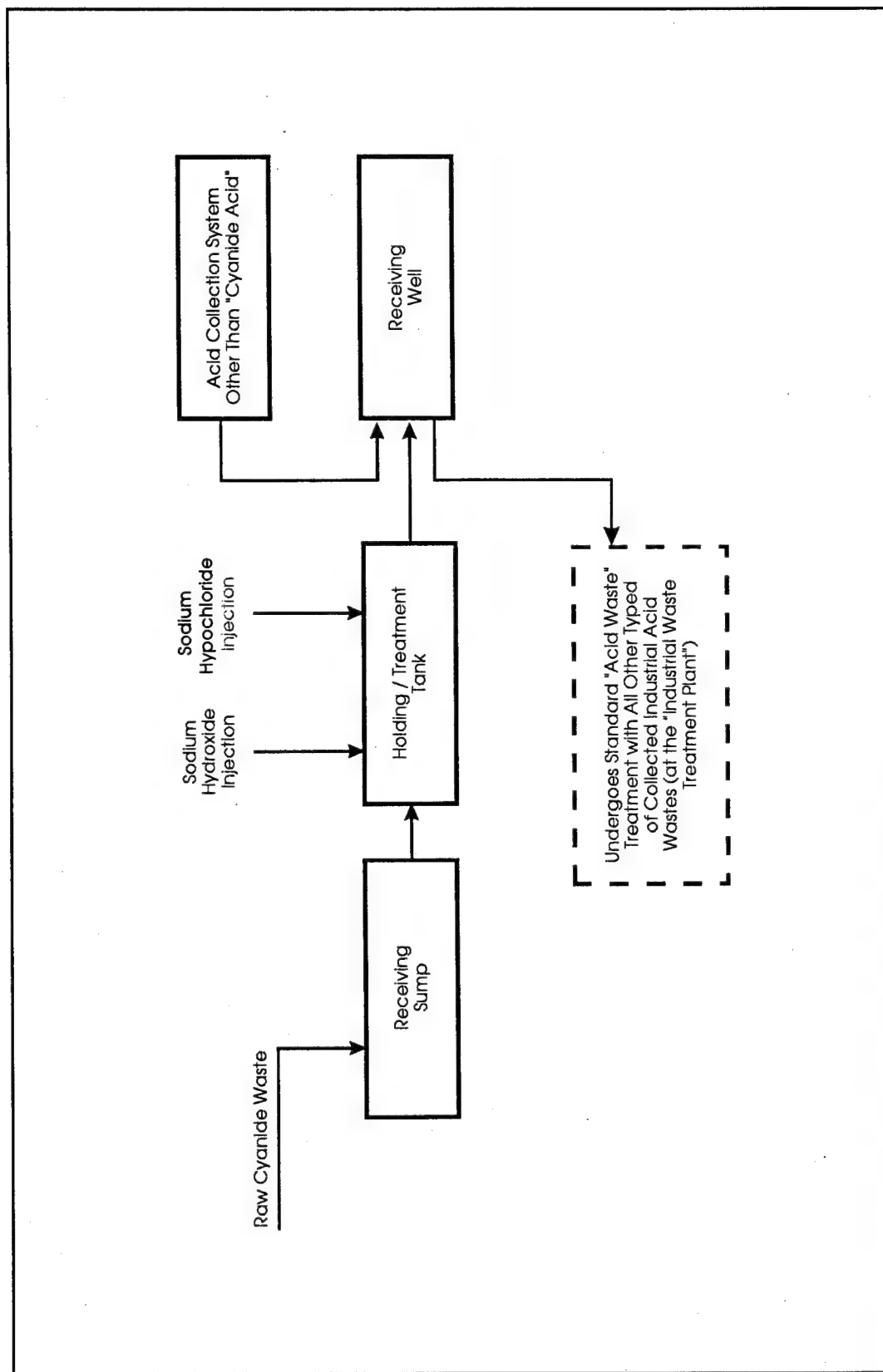


Figure 13. Cyanide waste treatment schematic, Watervliet Arsenal.

## 4 Technologies Available for Military Use

Two basic approaches can be used to reduce the quantity of sludge generated at AMC facilities. The first is pollution prevention. For example, source control in the production area may allow for the recovery and reuse of metals or the concentration of metals and reduction of water discharged. This approach also may include the development of new manufacturing techniques that produce less waste.

The second approach, end-of-pipe treatment, is to modify or change the unit process at the waste treatment facility. This may include changing the use or dose of a chemical for precipitating metals, or modifying the process, which will more efficiently capture solids or reduce the total volume or toxicity of the sludge. For all end-of-pipe treatment processes, a waste sludge will generally be produced; the objective is to produce a nonhazardous sludge or reduce the quantity of sludge produced.

### Pollution Prevention

Source control alternatives may include:

- reuse of waste battery acid
- recycling of automotive parts wash water
- electrowinning of plating bath
- recycling of bead blasting
- inventory control
- pollution prevention at plating operations
- solvent regeneration of granular activated carbon (GAC)
- total reuse.

#### *Reuse of Battery Acid*

Battery acid (32 to 37 percent sulfuric acid) typically contains trace concentrations of lead and cadmium. This waste generally has to be disposed of as a hazardous waste. Fort Riley, KS, has implemented a procedure whereby the acid is filtered, adjusted to 37 percent sulfuric acid, and reused.

Fort Riley calculated that the battery repair shop generated 7,200 gal per year of this waste at a disposal cost of \$27,900 per year. Current raw material costs are \$11,530. Recycling of the battery acid cost \$15,200 per year but would save \$36,000 per year in operating and disposal costs. AMC facilities may wish to consider a similar approach if they service equipment that uses acid batteries.

### ***Recycling of Automotive Parts Wash Water***

An alkaline automotive parts cleaner at Fort Riley, KS, contains trace concentrations of lead, chromium, cadmium, oil and grease, and dirt. This solution generally has a pH higher than 12. The treatment includes breaking of the emulsified oil and removing it by skimming and filtration of washwater to remove particulate material. The treated washwater either can be discharged to the sewer or reused within the process. The use of this treatment system is projected to save the facility \$107,100 per year. In general, AMC facilities that clean any type of military equipment in an alkaline bath may also investigate the possibility of recycling the washwater.

### ***Electrowinning of Plating Bath Water***

Electrolytic metal recovery (EMR), also referred to as electrowinning, is used successfully by electroplaters, rolling mills, printed circuit board manufacturers, and metal coating firms. Typically, a static rinse tank and an EMR unit are placed downstream from the process to remove bulk dragout (i.e., small spills as materials are removed from the chemical bath or rinsewater).

The EMR process works by passing an electrical current through a metal-bearing waste stream. As the current passes through the wastewater, electrochemical reduction of metal ions to elemental metals takes place at the cathode. At the same time, oxygen is evolved from the anode. Metal continues to be deposited on the cathode until the thickness of the deposit is about 1/2 in., at which point the power is shut off and the metal is recovered from the cathode, or the cathode is replaced.

Modern EMR units can capture up to 99 percent of the dissolved metals in a rinse tank. This results in less metal carryover or dragout to other rinse tanks and reduces the overall metal concentration in the waste stream. In addition, metals are captured without the generation of additional solids, as is common with end-of-pipe treatment with chemicals. The disadvantage of an EMR process is the high power cost associated with the removal of metals, especially when they are present in low concentrations.

### ***Bead Blasting***

Bead blasting has been used at Fairchild AFB for several years for paint stripping, which eliminates the use of methylene chloride as a solvent. Recently, McDonnell Douglas Aircraft Company also implemented this technology. Recycling of spent bead blasting media eliminates a waste stream that contains metallic solids such as chromium and cadmium. The reduction of the paint stripping waste stream also reduces the quantity of sludge at a central treatment plant.

### ***Inventory Control***

Inventory control involves identifying and tracking the chemicals used during facility operations and for waste treatment. Through inventory control, facilities may be able to reduce waste and to exercise better control of chemicals used in various areas. Tracking helps ensure that chemicals are used before their expiration date and eliminates the need for costly disposal measures.

An important aspect of inventory control is the reduction or prevention of waste. Through accurate recordkeeping and understanding of the process, wasteful practices can be identified and eliminated. Also, close tracking of chemicals helps to develop an inventory of wastes to be generated, which is helpful for reporting under the Superfund Amendments and Reauthorization Act (SARA) of 1986.

Control of chemicals and understanding how they are used is important. For instance, some chemicals, such as soaps and chelating agents, interfere with treatment processes; others may contain unacceptable levels of metals, which the treatment plant is not designed to remove; and some chemicals require treatment by methods completely different from those already being used, possibly involving major modifications to existing facilities.

The overall goal of inventory control is to screen all new products and chemicals to meet the environmental objectives of the facility. During the screening process, both the cost per pound\* to purchase and the cost per pound to dispose of must be considered.

Waltervliet Arsenal has developed a hazardous material information network (HAZMIN), which tracks the use of hazardous chemicals from the time of their arrival at the arsenal until they are used in the production process, hauled offsite, or discharged from the industrial treatment plant. Information gained from this program

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\* 1 lb = 0.453 kg.

also is being used in conjunction with the fire safety program. Fire teams have access to the program through an online system that provides information regarding the chemicals being used in specific areas of the facility. Thus, the fire response personnel are better informed on what to expect in terms of the flammability of the chemicals.

The Army also has determined the need for a customized material tracking system to identify the flow of products and waste generate at the production facility better. Realizing the need for such a program was a direct outcome of the pollution prevention program at Fort Eustis. Waste reduction evaluations at federal sites (WREFS) is sponsoring the development of this system.

### ***Pollution Prevention at Plating Operations***

Plating operations, whether electroplating or electroless processes, contribute to industrial waste primarily through rinse water streams and disposal of spent plating baths. Dragout of the process solution often occurs in the rinse tank. As the plating bath is used, impurities accumulate and the desirable chemicals are depleted. Eventually the bath must be disposed. Wastes can be minimized by implementing source control.

Because rinse waters are the primary waste streams from plating processes, minimizing dragout is a necessary first step for source control. The extent of dragout depends on such factors as the speed of withdrawing the work piece, drainage time, the surface tension and viscosity of the plating solution, and the physical shape and surface area of the workpiece (USEPA 1990). Factors such as speed of withdrawal and drainage time can be adjusted to allow slower transitions from the plating solution and longer time to drain excess liquid. The viscosity of the solution can be lowered by adding surfactants or raising the temperature of the plating solution. Although the addition of chemicals to reduce surface tension or viscosity may be attractive, the effects of such materials on wastewater treatment must be evaluated first. Lowering the viscosity allows fluids to drain off more freely, thereby reducing dragout volume. In addition, some traditional metal concentrations in the plating solutions are higher than required. Lowering some of the excess concentrations of metals would reduce the viscosity and, simultaneously, the volume of dragout. And, research has indicated that the proper orientation of the workpiece both in the plating bath rack and during drainage can help reduce dragout.

The underlying waste minimization goal of reducing dragout is to keep the metals in the process bath rather than allowing them to drain into rinse tanks. Other, less complicated dragout reduction measures may include installation of a drainboard that directs plating solution back to the process tank, a drip tank that can be used to

replenish the process tank, and a static rinse tank. Any measure that keeps process solutions in the process tank will reduce the load on the treatment plant and help minimize wastes.

Membrane separation processes, specifically reverse osmosis and electrodialysis, have been used to concentrate the liquid in rinse tanks. One of the primary factors in plating technology is the plating bath chemical concentrations. If the chemicals in the rinse tanks can be concentrated to an acceptable strength, they can be recovered and possibly reused. A detailed analysis of the ionic strength of the plating solution and rinse water is necessary to assess the impact of the accumulation of unwanted salts. Many plating processes use elevated temperatures so water will evaporate. Makeup water will contain dissolved solids, and these solids will accumulate. If the rinse water is treated to concentrate metals, other salts also will accumulate. However, an installation engineer should assess whether or not a deionized water supply is needed to prevent the introduction of unwanted salts into the plating bath.

Another approach to pollution prevention is to use methods that will extend the useful life of the plating bath. Such methods include new plating techniques, material recycling, and contaminant removal. However, these methods must be studied from two perspectives. Any changes to the care and upkeep of the plating solution will affect production. Therefore, any research must be a joint effort between production and environmental compliance.

The first goal of the research should be production oriented. Can procedures or techniques be changed without comprising the quality of plating? If the answer is no, that particular approach must be discarded. If the answer is yes, the research must address environmental issues. Will the new approach produce less liquid waste or metal contaminants that eventually become sludge for disposal? Is the new waste easier or more difficult to treat? If a smaller volume of waste is produced, it may meet the Army's goal of reducing hazardous waste but still may not be the best solution. If the waste is difficult to treat, can the desired effluent quality be produced to comply with Federal and local regulatory limits? If the waste is more difficult to treat, what is the cost of treatment, and does the process really produce less sludge for disposal? These questions can be compiled into a prioritized research program with the dual objective of evaluating alternative plating technologies or waste treatment techniques that are environmentally acceptable at a reasonable cost.

Any research into new plating technologies or techniques must be a joint effort. Production must continue to turn out a quality product at a reasonable or competitive cost for the Government. The changes in plating technology must produce a waste (assuming zero discharge cannot be attained) that can be economically treated to

comply with applicable regulations. This is an Army-wide problem. Even though the various arsenals plate or refurbish different equipment, they can use many of the same technologies.

Pollution prevention also can be practiced in the wastewater treatment process. In all likelihood, there will be some dragout in other waste streams. However, the amount of solids generated can be minimized by careful selection of chemicals. In comparison with lime, sodium hydroxide has been shown to produce less solids when precipitating chrome from solution and when neutralizing and precipitating cyanide-contaminated waste streams. Other waste minimization techniques may include using substitute plating materials, waste segregation for metals recovery, and efficient dewatering.

In many instances the critical factor in complying with regulatory limits for metals is capture of suspended solids. Chemicals are added to precipitate the soluble metals. Research has shown that the residual soluble metal concentration is a function of the chemical process, but compliance with the permit limit depends on the efficiency of solids capture in clarifiers and filters. Because of this relationship, many facilities favor the use of lime for alkaline precipitation. Lime produces a precipitate that flocculates and settles well and improves stability, but it produces considerable excess sludge. Many existing facilities use lime in spite of the large volume of sludge buildup.

New technologies that can be used in place of clarification or as a polishing step have come on the market. Microfiltration or ultrafiltration will remove the colloidal suspended solids that pass through clarifiers and conventional sand filters. Therefore, sodium hydroxide should be used for alkaline precipitation with a membrane process to remove all the suspended solids, or as a polishing step. Membrane processes are expensive, but they may be cost-effective when disposal costs are included in the analysis. Another point to consider is unreasonably strict discharge limits, particularly for direct dischargers like Tobyhanna Army Depot. A membrane process can produce an effluent with low metal concentrations because of their ability to remove not only suspended solids but also colloidal particulates smaller than 0.45 micron ( $\mu$ ). By definition, solids less than 0.45  $\mu$  in diameter are considered dissolved solids.

### ***Solvent Regeneration of GAC***

Removal of organic contaminants from an industrial waste stream is possible through the use of GAC, as is practiced on some production lines at the KAAP. Unfortunately, after the adsorptive ability of the carbon is diminished, the carbon is considered spent and must be regenerated or disposed of. KAAP currently sends spent carbon off post for fuel blending, which is ultimately a thermal destruction technique. As a result, the plant reaps no internal recycling benefit from the spent carbon.



Carbon regeneration is a process whereby adsorbed organics are removed from the spent carbon. Typically, spent carbon is regenerated by heating it so organics are volatilized and released in gaseous form. Thermal regeneration has been shown to produce near-virgin adsorptive capacity with only a slight loss of carbon. However, because of the nature of some of the organics adsorbed, not all spent carbon can be regenerated thermally. The explosives adsorbed by carbon are so energetic that the carbon must be regenerated by another process such as solvent extraction (Balasco, Chen, and Field, November 1987).

Solvents remove organics from spent carbon by breaking the bonds between the adsorbed material and the activated carbon. Unlike thermal regeneration, when organics are destroyed by volatilization, organics removed by solvent processes remain in solution unless a chemical is added to oxidize the organic. Considerable work has been done studying the capabilities and characteristics of inorganic and organic solvent regeneration (Martin and Ng 1984). Inorganic chemical reagents with oxidizing powers generally were found to be ineffective. Organic chemical reagents with solubilizing powers were found to be more effective, but they still were far less effective than thermal regeneration.

Although solvent regeneration is known to be less effective than thermal regeneration, the characteristics of the adsorbed material may preclude heating the carbon. As a result, solvent regeneration still will allow some reuse of spent carbon and reduce the amount of waste produced. As a parallel effort, a research effort can be initiated to determine the critical energetic compound loading rate that allows thermal regeneration. Alternately, a new generation adsorbent could be developed for more effective removal and regeneration.

### **Total Reuse**

Many of the operations at the Army facilities involve the use of chemicals that ultimately are discarded along with the solids generated during industrial waste treatment. Total reuse is gaining more popularity because of stricter discharge standards and the advantage of recycling chemicals from the waste stream (Army Material Development and Readiness Command, November 1986).

With rising costs of operation and treatment, many industries are realizing the benefits of total reuse. There are advantages such as reduced chemical costs, reduced disposal costs, and treatment to a minimum level of discharge. However, other costs are likely to be increased by adopting this holistic treatment approach. To effectively recycle many of the contaminants in the waste stream, more sophisticated treatment devices will be needed. The traditional chemical reaction tank followed by a clarifier

probably would not achieve the necessary degree of removal by these simple processes. However, the accumulation of dissolved solids will often be a major obstacle to reuse of water. Additionally, treatment practices that include reverse osmosis, ultrafiltration, EMR, or even crystallization may be necessary. New generation ion exchange resins, new adsorbents that can selectively remove metals, and new membranes are of interest. Also, treatment devices will need to be placed strategically to ensure that treatment is occurring in the places where the targeted contaminant is most highly concentrated and has not mixed with other waste streams.

Total reuse is already familiar to other industrial waste generators. General Electric Aircraft Engines (GEAE) is developing a total reuse program for treating waste streams produced from the injection of quench water into exhaust gases during testing of jet engines and components, and from cooling tower blowdown. Through the use of oil/water separators, air stripping, reverse osmosis, and vapor recompression, GEAE will produce a water of suitable quality for reuse as quench water (Kobylnski, Shanker, and Patel April 1992).

## **End of-Pipe-Treatment**

The second approach for reducing sludge generation is modifications to end-of-pipe treatment. Modifications can be made to the liquid treatment processes that produce the sludge or to the sludge handling processes to reduce the sludge mass or volume. These processes include:

- chemical addition
- electrochemical process
- membrane technology
- crystallization of RDX/TNT
- dewatering
- biological treatment of metal sludge.

### ***Chemical Addition***

The use of chemicals for the removal of suspended solids or dissolved metals from industrial waste is a commonly practiced method of industrial waste treatment. Often the choice of the chemicals is not based on optimizing the overall process but rather on factors such as cost and availability. As a result, the chosen chemical may produce larger quantities of sludge than would be produced by another equally effective chemical. Optimization of chemical addition is a management practice that can be

used to customize treatment processes to reduce costs, i.e., chemical use, and solids generation (Figure 14).

The removal of metals from the process waste is frequently the goal of industrial waste treatment. Because a considerable portion of the metal may be in a dissolved state, industrial waste treatment methods often attempt to precipitate the metals and allow them to settle out of solution. Precipitation of dissolved metals is achieved by chemical addition, with close attention to the pH of the wastewater. pH can result in the precipitation of many pH-sensitive metals as metal hydroxides. Common metals identified during site visits as needing to be removed include cadmium, chromium, lead, and zinc. Cadmium, chromium, and zinc were found in the wastewater at the depots and arsenals; lead was the primary metal of concern at KAAP. Chemicals also are added at the Anniston Army Depot industrial waste treatment facility to assist in the removal of oil and grease.

All four facilities studied used different chemicals for metals removal. Lime is the most commonly added chemical for the removal of cadmium and zinc. At the Anniston Army Depot, lime also was used to remove lead and chromium. Lime precipitation can produce three times as much sludge as other precipitating chemicals such as soda ash ( $\text{Na}_2\text{CO}_3$ ) or caustic soda ( $\text{NaOH}$ ) (Patterson 1985). Lime has been chosen for alkaline precipitation in many cases because of both costs and the capability to produce a clarified, low-solids effluent. Although caustic soda and soda ash may produce less sludge, coagulant aids, such as polymers or magnesium sulfate, also are needed to produce a low-solids effluent. On occasion, the facility's NPDES permit also may require effluent filtration when alkaline precipitating chemicals other than lime are used.

Several methods of chemical treatment are available for chromium removal. The selection of a treatment will be based on the oxidation state of chromium. If chromium is present in the hexavalent form ( $\text{Cr}^{6+}$ ), it cannot be chemically precipitated; it first

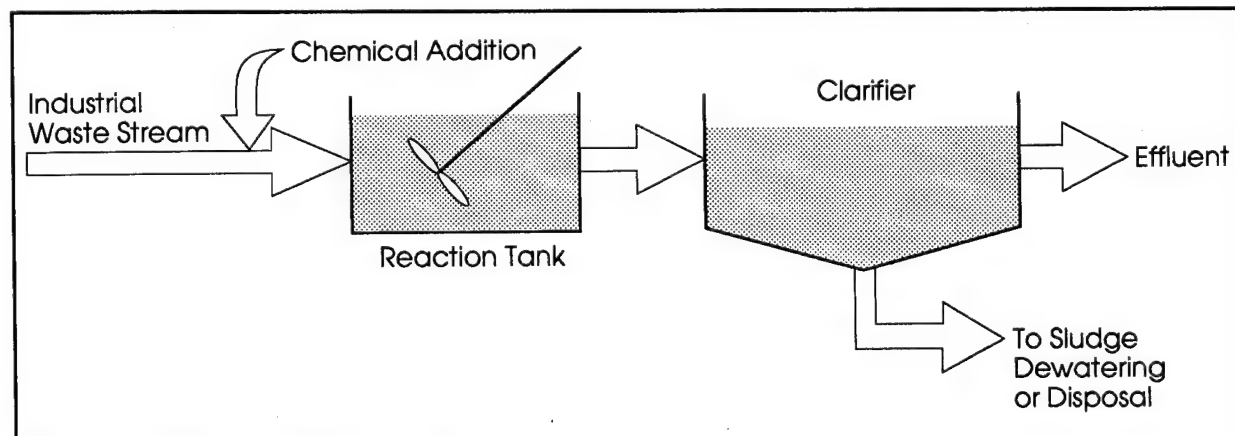


Figure 14. Chemical precipitation process.

must be reduced to the trivalent form ( $\text{Cr}^{3+}$ ). Trivalent chromium will precipitate as chromium hydroxide at pH 8.5. Chromium also may be present as a suspended solid, such as in paint chips, with only a small fraction of the chromium soluble in water. In this case, direct filtration will remove the chromium associated with the suspended solids, and the dissolved or soluble fraction will pass through the filter.

Hexavalent chromium can be removed from the waste stream by chemical reduction followed by chemical precipitation and settling. In the first step, a chemical such as sulfur dioxide, sodium bisulfite, sodium metabisulfite at low pH, or ferrous sulfate at neutral pH is used to reduce dissolved chromium in its soluble hexavalent form to a less soluble trivalent form that can be precipitated out of solution with the other metals by adjusting the pH of the wastewater. Chemical precipitation converts the metal from a soluble species into suspended solids, i.e., particulates that settle out of solution or solids that can be removed by filtration. As a result, metals are precipitated and allowed to settle under quiescent conditions. At Tobyhanna Army Depot and Watervliet Arsenal, chromium is removed from the waste by chemical reaction followed by alkaline precipitation. At Watervliet Arsenal, sulfide precipitation also can be used.

Precipitation using sulfide is another common method of removing lead, cadmium, copper, zinc, nickel, silver, and other metals, except chromium. The KAAP uses this process for the removal of lead styphante. Sulfide precipitation is a solubility product-driven process that is somewhat different from alkaline precipitation. In alkaline precipitation, a pH range is defined that results in a minimum solubility of a given metal, but sulfide precipitation is controlled by the molar ratio of free sulfide with the metal ion. The chemical dose for alkaline precipitation is determined by the desired pH and alkalinity or acidity of the wastewater; and the chemical dose for sulfide precipitation is based on the concentration of metal to be removed. Therefore, a general guideline can be established which states that alkaline precipitation is used for highly concentrated waste streams and sulfide precipitation is used for more dilute metal concentrations.

Sulfide precipitation produced an effluent with lower soluble concentration than alkaline precipitation. The metal sulfide compounds are much more insoluble than the respective metal hydroxides. Care must be taken when using sulfide precipitation not to add too much excess sulfide. According to the chemical theory for solubility product-driven reactions, a high dose of sulfide will result in a very low concentration of soluble metal; however, there are limits. If the sulfide dose is too high, it is possible soluble metal complexes. Treatability tests always must be preformed to determine if sulfide precipitation is practical.

Sulfide precipitation can never be used concurrently with alkaline precipitation. These two processes can be used only in a series, with the removal of the hydroxide precipitates or sludge before the sulfide addition. The metal sulfides are insoluble so the soluble metal concentration is reduced to an extremely low value. If the metal hydroxide precipitate is present, it will dissolve. As long as metal hydroxide precipitates are present, the equilibrium between the soluble metals and the hydroxide compound will control the soluble metal concentration in the treated effluent.

Two forms of sulfide can be used for precipitation of metals: soluble sulfide such as sodium sulfide, calcium polysulfide, or sodium hydrosulfide, and a less soluble form, such as ferrous sulfide. Both have advantages and disadvantages. Soluble sulfides may generate hydrogen sulfide fumes from the chemical storage tanks, from the liquid treatment system, and from the sludge handling processes. Hydrogen sulfide fumes in an enclosed space are flammable and highly toxic. The Occupational Safety and Health Administration (OSHA) has developed safety precautions and allowable exposure limits. Ventilation must be included in the design of any sulfide treatment system. The use of soluble sulfides produces the least amount of sludge.

The insoluble sulfide process (ISP) uses ferrous sulfide to limit the concentration of free soluble sulfides and the potential for hydrogen sulfide generation. ISP produces more sludge than the soluble sulfide methods, and it is a patented process. When properly designed and operated, sulfide precipitation can be used at any Army installation.

Chemical addition for the removal of metals from process waste streams is a proven treatment approach and is well suited for automatic control. However, it has the disadvantage of generating metal sludge.

Because each chemical added for the removal of metals can affect the quantity of solids generated considerably, the selection of a chemical to produce the lowest quantity of solids with the highest metal removal efficiency is critical. Optimizing chemical use is a simple method of reducing sludge production. To optimize the treatment process properly, bench-scale and pilot-scale testing should be conducted before full-scale implementation because of the potential for solids carryover from the clarification process.

### ***Electrochemical Process***

In the electrochemical process, a direct current is conducted through a cell containing carbon steel electrodes, which generates ferrous ions into the wastewater stream. When hexavalent chrome is present, the ferrous ion acts as a reducing agent, which

reduces hexavalent chromium to the insoluble trivalent state. The reaction is as follows:



Other heavy metals such as copper, lead, nickel, zinc, tin, and cadmium are coprecipitated with the ferrous hydroxide. This reaction proceeds under favorable conditions when the pH of wastewater remains between 6 and 9.

A bipolar arrangement of electrodes is used within the electrochemical cell. One side of each electrode is the anode; the other is the cathode. Ferrous ions are generated at the anode; water is disassociated at the cathode to form hydrogen and hydroxyl ions. The small amount of hydrogen gas formed is vented from the top of the cell. Approximately 5 kilowatthours (kWh) is required per pound of heavy metal removed. A typical cell operates at about 25 amperes DC. The voltage on the cell is a function of electrical conductivity and can vary from 40 to 600 volts DC.

In normal operating conditions, the electrochemical process is operated on a continuous, once-through basis. Wastewater is delivered to the cell at a pressure of 25 psig with a detention time of 5 seconds. Wastewater flows from the electrochemical cell to a mixing chamber where 1 to 2 ppm of anionic polymer is added to assist flocculation before the wastewater enters the clarifier. Lamella-type (slanted, parallel plate) clarifiers frequently are used in the process because of the small space they require. The metal hydroxides and other suspended solids are separated from the waste streams, and sludge from the bottom of the clarifier is sent through a filter press for dewatering to approximately 30 percent solids.

The Anniston Army Depot uses the electrochemical process to remove chromium from contaminated groundwater. Sludge generated from this treatment facility is disposed of at an onsite landfill.

### ***Membrane Technology***

Membrane technology has become increasingly popular in applications that involve the removal of colloidal contaminants from solution. Reverse osmosis, a membrane technology, can separate dissolved salts or metals from water, which produces a brine stream with a high dissolved solids concentration.

Membrane separation is a concentration process in which the membrane acts as a selective barrier. Five major membrane separation processes are used in industry: reverse osmosis, nanofiltration, ultrafiltration, microfiltration, and electrodialysis. The semipermeable membrane allows only the water or solvent to pass through,

leaving salts and dissolved metals behind. As a result, two output streams are produced: one concentrated with salts and dissolved metals and one relatively clean. The difference between reverse osmosis and nanofiltration is salt rejection efficiency. Reverse osmosis membranes are operated at higher pressures and have metal rejection efficiencies of 50 to 90 percent. High pressure reverse osmosis membranes can reject from 95 to 99 percent of all dissolved solids.

Ultrafiltration is a membrane process used to remove colloidal solids and some organics; however, it does not work well in removing truly soluble metals. Ultrafiltration frequently is used to remove soluble oil and grease from industrial waste streams and can reduce total toxic organic (TTO) concentrations.

In microfiltration, separation is accomplished by cross flow filtration. Traditionally, microfiltration has been used to remove suspended solids and colloidal solids. Recent advances, which include increased material compatibility over pH ranges from 2 to 12 and reduced pore sizes down to  $0.1 \mu$ , have led to new applications. Microfiltration is commonly used in conjunction with chemical precipitation and replaces clarification.

An electrical field is used in electrodialysis to cause ions to move through selective membranes. The membranes are assembled in stacks and produce alternating chambers of low total dissolved solids (TDS) and high TDS water. The major difference between electrodialysis and reverse osmosis is product water quality. Reverse osmosis can produce a water lower in TDS, of essentially distilled water quality; electrodialysis-produced water typically has a TDS concentration of 100 to 200 mg/L.

Membrane processes can be used to treat wastewater unique to the Army. Reverse osmosis and electrodialysis can be used to concentrate rinse waters for reuse or as a concentration step before electrowinning. Previous studies at Federal facilities have indicated that reverse osmosis can be used successfully to treat plating bath wastewater, and that the permeate produced in the treatment process can be recovered and reused.

### ***Crystallization of RDX/TNT***

The solubility of RDX and TNT in solution is dependent on a number of conditions, including temperature. As the temperature is lowered, the solubility of these compounds is diminished and causes some of the dissolved compounds to crystallize. This phenomenon can be used in the treatment of industrial wastes, especially wastes that require more cautious handling. A portion of the waste stream is circulated through a cooling unit where crystallization takes place (Figure 15). The crystals can be settled out of solution by passing the cooled fraction of the waste stream into a holding tank



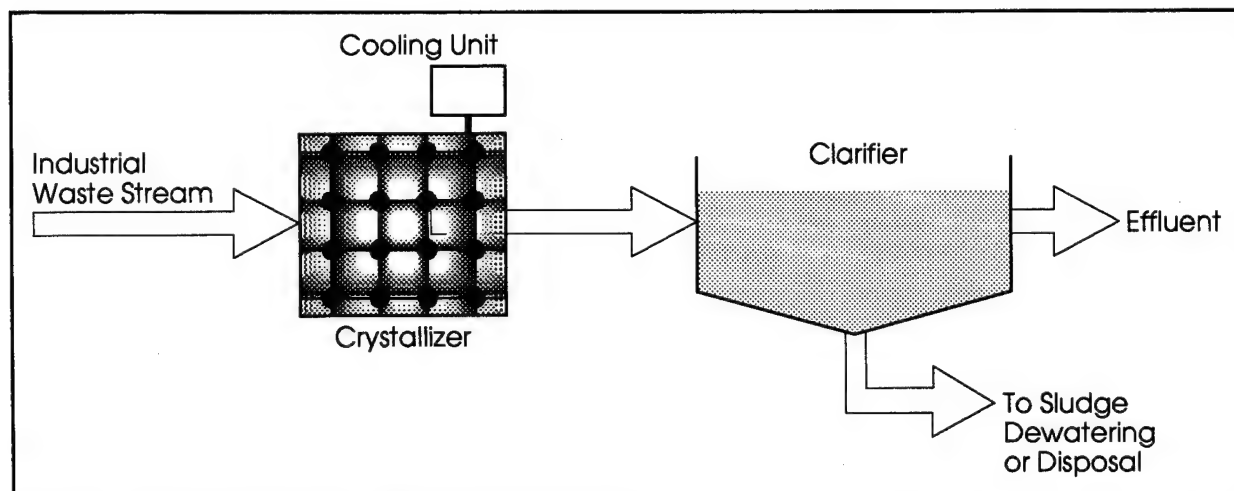


Figure 15. Process schematic crystallization of RDX/TNT.

or a clarifier. Experience has shown that RDX essentially can be removed from solution when the temperature is between 15 °C (59 °F) and 20 °C (68 °F), but temperatures near freezing (0 °C) are required to remove TNT to only 100 ppm (U.S. Army Materiel Command 1967).

The sensitivity of RDX and TNT to temperature still is being used in treating explosive wastes generated at the Milan Army Ammunition Plant, Milan, TN. The temperature of explosive wastes generated at the plant is near 82 °F (28 °C). To prevent deposition of explosive solids in the pipes as the waste cools, they are brought into contact with a cooling coil in the production line sump allowing crystallization and deposition to occur. After the waste stream is transferred to the central treatment area, it is further cooled. The result is a reduction in contaminant load ahead of the upflow activated carbon filters. Crystallizing some of the RDX/TNT before filtration reduces treatment costs by extending the life of the carbon filters.

### **Dewatering**

Dewatering is a common method of reducing the volume of sludge produced in liquid waste treatment processes. Conventional dewatering systems use gravity, atmospheric pressure, and mechanically produced pressure to remove excess water from the solid mass. Conventional dewatering systems include belt filter presses, centrifuges, plate and frame presses, and vacuum filters.

Plate and frame presses are a popular choice for dewatering industrial wastewater treatment plant sludge. Typically, the sludge should be thickened by adding a polymer prior to clarification. A plate and frame filter press can produce a filter cake of more than 25 percent solids, with no free water. However, dewaterability depends on the type of sludge. Hydroxide sludges (alkaline precipitation using sodium hydroxide or



alum) are difficult to dewater, but lime sludges (hydroxide precipitation using calcium oxide or calcium hydroxide) can be dewatered to 35 to 45 percent solids. With recent innovations to plate and frame presses, and depending on the nature of the solids being filtered, a cake of up to 50 percent solids is possible.

Belt filter presses and vacuum filters produce a sludge cake ranging from 15 to 25 percent solids using gravity and atmospheric pressure for water removal. However, as the sludge proceeds on the belt filter, the belts are squeezed together and eventually may be passed through rollers to remove additional water. Centrifuges, which essentially are rotating bowls in which solids are separated from liquid by centrifugal force, have been used by both thickening and dewatering. Advances in centrifuge technology have resulted in better dewatering performance. As with plate and frame filter presses, the filter cake concentration will depend considerably on the type of sludge.

Optimizing dewatering is an obvious approach to reducing costs through reducing the waste. In many cases, dewatering equipment capable of producing a cake with 25 percent solids is used. Typically, disposal costs are determined by the weight of the material landfilled. If a material is dewatered to 25 percent solids, the generator ends up paying disposal costs for the 75 percent of water remaining with the solids. Obviously, by reducing moisture, through the use of better dewatering methods, the weight of material to be disposed of, and thus the disposal costs, can be reduced. The Anniston and Tobyhanna Army Depots use plate and frame filter presses for the dewatering of their industrial sludge. Watervliet Arsenal uses sludge drying beds.

***Microwave thickening and dewatering.*** The use of microwave energy for thickening and dewatering industrial sludge has been tested as an alternative to conventional methods (Collins, Mitra, and Pavlostathis, October 1990). The attraction of microwave technology lies in its capability to dewater and dry sludge in a single step.

Microwave technologies are useful because microwave energy evaporates moisture from below the surface as well as at the surface of the sludge. As a result, sludge can be dewatered or dried rapidly. However, microwaving has been observed to consume large amounts of electrical energy. Consequently, a microwave system is not economical for thin sludges that can be dewatered by conventional means, but it may be used to supplement an existing dewatering system. Because conventional dewatering can achieve 15 to 35 percent solids, microwave technology could be used to further dry the solids to 50 percent, which would help reduce the volume and weight of sludge for disposal.

Microwave dewatering and further drying may be beneficial to Army facilities, especially if dewatered sludge could be dried to 50 percent or higher solids concentration. The corresponding reduction in sludge volume would save hauling and landfilling costs. However, the problem is the cost of electrical energy. An economic evaluation should be made to determine whether the reduction in disposal costs justifies the additional energy costs.

**Ultrasonic thickening.** Ultrasonic thickening is a fairly new application of an old idea. Ultrasonic thickening occurs through the action of mechanically induced vibrations that propagate through the material as elastic waves. Vibration allows solids to consolidate and separate from the liquid.

Ultrasonic thickening has been used to improve the dewatering characteristics of wastewater sludge. Through the combination of ultrasonic action and conventional dewatering methods, increased product yields and energy savings can be gained at facilities that practice extensive dewatering and drying.

Ultrasonic thickening could benefit Army facilities by reducing energy costs and maintaining high sludge yields. However, the cost, commercial applications, and reliability of ultrasonic equipment are not known.

**Conventional heat drying.** Heat drying offers a number of waste reduction and cost saving benefits to Army facilities. Typically, landfills or disposal sites charge "tipping" fees for sludge, usually on a fixed amount per pound of material placed in the landfill. Considering that dewatered sludges still contain 40 to 80 percent water, it is apparent that substantial savings in landfill disposal costs could be realized by removing additional water from the dewatered sludge. Heat drying would enable the Army to pay for disposal of the solid sludge mass only and eliminate the unnecessary cost of disposal of the water.

Conventional heat drying is a physical process of removing water. In recent years, the interest in heat drying of sludge has increased partly because of technological innovations and changes in attitudes. Heat dryers for the drying of municipal sludge are designed to produce a material that has a beneficial use and is aesthetically acceptable to the public.

A conventional heat dryer removes moisture from sludge either directly through contact with the heat source or indirectly by contact with a heat exchange surface. The decision whether to use direct or indirect heating depends on factors such as the consistency of the material being dried, the degree to which moisture should be removed, and the amount of sludge to be processed. Typically, direct contact dryers

perform best at temperatures near 800 °F and produce a material that is bone dry (80 to 85 percent solids). However, indirect contact dryers operate at temperatures near 400 °F and permit excellent control of the final product consistency.

Many types of dryers are available to meet differing drying needs. One in particular, the belt dryer, has found application when small quantities of sludge are produced. The belt dryer is used simply by placing thickened or dewatered sludge on a conveyor belt and allowing the sludge to progress through the dryer. Some belt dryers incorporate a heated belt along with heated overhead air to dry the sludge to the desired level.

### ***Biological Treatment of Metal Sludge***

Although current metal sludge treatment technology relies on basically physical and/or chemical processes, biotechnology is a promising area for further development. The current status of biotechnology in metal sludge treatment, based on a literature search, will be available in a USACERL Technical Report (Kim, Cha, and Song 1995) and will serve as a reference for future metal sludge-related research and development (R&D). Innovative biological treatment technologies for metals include biosorption, metals treatment and precipitation by sulfate-reducing bacteria, and bioleaching.

## **Delisting of Chemical Sludges**

The sludge generated at all four Army facilities visited is considered hazardous waste. The sludge is considered hazardous because the USEPA defines wastes generated from these operations as hazardous waste. However, after treatment of the waste, there is a question whether the sludge generated in the treatment process still has the characteristics that define it as a hazardous material. In many of the treatment processes, wastes are neutralized and precipitation occurs to the extent that it, in effect, dilutes the concentration of metals captured in the sludge. With this in mind, the Army could attempt to have the sludge removed from hazardous classification. The process of removing a hazardous classification is called delisting.

Any person may petition the USEPA to exclude or "delist" a particular facility's listed waste, even if the waste is considered hazardous. However, the process is time consuming and costly, and frequently it does not result in the delisting of the waste. To pursue delisting, the petitioner must demonstrate to the USEPA's satisfaction that the waste in question does not meet any of the criteria under which it was classified as hazardous. In making a decision, USEPA officials will take into account whether the waste exhibits other properties that might make it hazardous. The tentative

decision will be published in the *Federal Register* for public comment, and it may be considered in an informal hearing.

Having Army-generated sludges delisted would be extremely beneficial because it could open up numerous reuse and disposal venues. Rather than being restricted to landfilling hazardous waste, the Army could pursue options to get rid of the sludge at a lower cost, or even generate some revenue. However, the USEPA has demonstrated its reluctance to grant delisting of wastes. Considering the magnitude of other plating operations nationwide and their reactions if the Army's chemical sludge were to be delisted, it is unlikely that the USEPA would easily grant a delisting to the Army. However, the delisting of spent activated carbon that contains explosives may be a possibility. At least one state has allowed the delisting of this material, if it passes the Bureau of Mines' Zero Gap and Deflagration to Detonation Transition tests (Kristoff, Ewing, and Johnson, January 1987).

### **Federal Regulations Update/Permit Renewal**

The USEPA is required to prepare a schedule for the establishment of the additional effluent guidelines or categorical standards. Many of these new guidelines may have an impact on Army facilities. Effluent guidelines for such industries as metal manufacturing will impact AMC facilities that repair military equipment. A preliminary data summary indicated that many of the pollutants currently regulated by 40 CFR 413/433 also will be regulated by this metal manufacturing guideline. Other effluent guidelines that may affect Federal facilities include industrial laundries and hazardous waste treatment facilities.

One of the USEPA's oldest environmental programs is the water quality standards. Water quality programs have three phases: numerical quality, aquatic toxicity limits, and sediment standards. Numerical water quality standards were established in the early 1980s. In 1987 and 1988, the USEPA formally established aquatic toxicity limits and began incorporating them in NPDES permits. Sediment standards currently are being established by the USEPA.

One of the changes to the NPDES program is the incorporation of water quality standards into NPDES permits. This is the case for the new NPDES permit for the Tobyhanna Army Depot, which currently treats industrial wastewater and discharges into a domestic wastewater treatment plant, a Federally-Owned Treatment Works (FOTW). The updated permit will include maximum daily limits for metals and nutrients. In many cases the metal limits may be the same as the state water quality standard, especially if the sanitary plant discharges to a small receiving stream.

## 5 Improvement Strategies

### Short-Term Improvements

Visual observations at each facility can be used to project short-term improvements in sludge management. These observations are specific to each site and may be difficult to extrapolate on an Army-wide basis.

#### ***Kansas Army Ammunition Plant***

Data collected during the site visit indicated that the KAAP has two major sludge/solid waste streams which have to be managed: lead sludge produced in Building 700 and spent activated carbon. Currently lead sludge is disposed of on-site in a long-term landfill, and spent activated carbon is sold or disposed of through the Defense Reutilization and Marketing Office (DRMO). The spent activated carbon has been delisted by the State of Kansas. Both of these disposal methods appear to be adequate, and no short-term improvements are recommended.

#### ***Anniston Army Depot***

Four major sludge streams are generated at the Anniston Army Depot: hazardous sludge from the industrial treatment facility, nonhazardous sludge from the industrial treatment facility, sanitary sludge, and sludge from the groundwater treatment facility. Facility personnel indicated that 2.1 million pounds (957,453 kg) of sludge was shipped off site for disposal in 1992. The use of lime in the treatment process contributed to the large quantity of sludge generated. Short-term improvements that could be examined include:

- Volume reduction of metal finishing sludge. Currently the metal finishing sludge is segregated as a listed hazardous waste. Heat drying will reduce the mass of sludge for disposal and result in a cost savings because the cost for solid waste disposal is on a dry weight basis. Drying could be accomplished by microwave, infrared, or forced air processes. (Currently, the nonhazardous sludge is dried, and the facility realizes the benefits in cost savings.)

- Optimizing chemical use. A number of chemicals are used at this facility for the treatment of industrial wastes. Currently lime is used to raise pH to 11.8 for metals removal and as a bulking agent in sludge dewatering by a plate and frame filter press. Treatment chemicals could be evaluated to determine whether:
  - chemical use can be optimized, thereby minimizing the mass of sludge cake produced, without adversely affecting treatment quality
  - alternative chemicals such as magnesium sulfate, alum, polymer, starch xanthate, or clay can be used as coagulant aids rather than lime to reduce chemical sludge volumes and disposal costs
  - polymer can be used to remove oil and grease from the stream cleaning waste rather than lime to reduce sludge production?

### ***Tobyhanna Army Depot***

The Tobyhanna Army Depot produces two kinds of sludge the facility has to manage. Currently the industrial waste is mechanically dried, and the sanitary sludge is dewatered on drying beds. Both of these technologies appear to be producing small quantities of sludge that must be disposed of off-site, and no short-term improvements are recommended. In the short term, the facility should examine the possibility of using sanitary sludge as a soil amendment in the mitigation of abandoned mine sites/operating coal mine sites. Currently the metals content in the sanitary sludge limits disposal on land based on 40 CFR 503 land application criteria. The facility is searching for the source of metals in the sanitary system because the IWTP effluent is not the source of the metals.

### ***Watervliet Arsenal***

The majority of the sludge generated at the Watervliet Arsenal comes from the treatment of metal finishing wastewater. Currently, this sludge is delisted. The delisting petition with the USEPA began in 1982 and culminated with final approval in late 1985. The delisting petition was formally granted in January 1986. Watervliet Arsenal personnel sample the sludge once or twice a year, with an off-site certified laboratory performing the TCLP analysis to verify its continuous delisted status. The State of New York regulatory personnel are watching the facility carefully for any changes to the waste treatment processes. If the sludge is ever relisted, it will be classified a hazardous waste under RCRA. Therefore, in the short term, no changes are recommended.

## Long-Term Strategies

The reasoning behind the development of long-term strategies is threefold: to evaluate processes or modifications that reduce the quantity of sludge generated for disposal as a cost savings project and to comply with the Army directives to reduce hazardous waste, to evaluate liquid treatment techniques that reduce solids production and improve effluent quality in response to the water quality standards now being written into NPDES permits and pretreatment programs, and to develop strategies to delist the sludge or to respond to the possibility that the delisting of certain wastes may be revoked. These strategies or alternatives for reduction of solids have been developed on a site-by-site basis. Ideas are presented that are specific to the individual facilities visited as part of this project. Even though the ideas are site specific, other AMC facilities may find approaches for solving solid waste issues.

### *Kansas Army Ammunition Plant*

- Heat regeneration of activated carbon has been practiced for many years. Solvent regeneration works without using heat. KAAP personnel reported that heat regeneration of carbon had been tried; however, RDX and TNT are so energetic that the carbon is pulverized during thermal regeneration.

Solvent regeneration can remove the RDX and TNT from GAC. The RDX and TNT then must be removed from the solvent. Low temperature vacuum distillation is a method of possible solvent recovery; membrane separation is another method. Solvent recovery for reuse is the key to the economic viability of this procedure. If the GAC can be regenerated, the annual quantity of carbon disposed of can be reduced. This approach is probably not cost effective at this time because the GAC has been delisted by USEPA Region VII. Should the delisting be revoked, solvent regeneration may be a possible approach to reducing the cost of GAC disposal. It should be noted that a liquid waste stream of solvent and concentrated RDX and TNT would be produced. Incineration would be an appropriate technology for the disposal of this waste.

- Crystallization of RDX is a proven technology. It has been used at the Milan Army Ammunition Plant with much success. Crystallization of RDX using a chiller allows more of the material to settle out ahead of the GAC columns and decrease the amount of spent GAC to be disposed of annually. The most costly factor of this approach is the lowering of the temperature of the waste stream. An economic evaluation should be performed to develop a cost-benefit relationship to determine if further development of this approach is warranted for KAAP. There may be a break-even point based on production activity at which crystalli-



zation becomes cost effective. Once again, the economics of this approach may not be favorable because spent GAC is currently delisted. The economic analysis should evaluate both the current disposal cost of GAC as a delisted waste and the disposal cost of GAC as a hazardous waste to determine whether further development of this approach is economically practical.

- Currently KAAP uses a crude settling chamber to remove particulate explosives ahead of filtration. The frequency of cleaning the filters will be reduced if more solids can be removed. As each filter is cleaned, some anthracite filter media is removed with the explosives, thereby increasing the mass of waste for disposal. Better solids removal also will extend the life of the downstream diatomaceous earth (DE) filters and reduce the mass of hazardous waste for disposal. Polymer addition should be evaluated as well as replacing the settling chamber with a more efficient system. An inclined plate settler may more effectively remove solids, but the large plate surface area may not be desirable from a safety perspective. Batch settling tanks or a continuous gravity separator designed to enhance solids removal should be evaluated.
- Aquatic toxicity testing has been performed at the NPDES permitted outfall from the 700 Line. High ammonia concentrations and a high conductivity are suspected of causing the toxicity. A study should be undertaken to determine if the 700 Line waste should be routed through the sanitary wastewater treatment plant. Combined treatment of the industrial and sanitary wastes would be effective in removing ammonia if the sanitary system is nitrifying and for the dilution of total dissolved solids (conductivity). As long as the sanitary wastewater sludge does not become contaminated with lead and the combined sanitary plant effluent does not exhibit toxicity, advanced treatment of the 700 Line wastewater can be avoided. The aquatic toxicity testing requirement is part of the Federal and state water quality standards that will soon affect all Army installations.
- Wastewater produced in the 900 Line contain RDX and TNT. an advanced oxidation process (AOP) should be evaluated to see if the GAC columns can be operated longer. The AOP process will alter the chemical structure of RDX and TNT. Because highly energetic materials are being oxidized, the safety aspects of this approach must be carefully evaluated. Only soluble RDX and TNT are to be treated, so the AOP approach should meet Army safety criteria. The objective of this approach is to destroy the RDX and TNT to determine if the GAC column running time can be extended, or if the GAC system is even needed. AOP processes usually do not produce a solid waste, so this process could be implemented as a cost saving project or as a way to reduce hazardous waste generation.



- Wastewater produced in the 900 Line contain RDX and TNT. The use of surfactants should be evaluated to determine if the running time of DE filters and GAC columns can be extended. Previous research using the surfactant Duomeen T appeared to be promising in terms of fixation of TNT and RDX (Freeman and Colitti, April 1980).

### ***Anniston Army Depot***

- The facility should consider evaluating the impacts of changing regulations on the treatment facilities. The USEPA is establishing new regulations for facilities that manufacture metal products and machinery. The Army should be proactive in responding with comments to the USEPA when the regulation is proposed and should begin researching how to comply with the new requirements.
- Depot personnel indicate that the steam cleaning waste stream contains oil products. An American Petroleum Institute (API/CPI) gravity oil/water separator should be installed to remove oil. The oil could be used as waste energy if a waste incinerator is available. The steam cleaning wastewater currently is treated with lime. The solids produced from the lime absorb oil to make floc particles heavy enough to settle. Oil has a specific gravity lower than that of water, so the oil tends to float. By removing as much free, floatable oil as possible before the lime treatment, less lime will be needed and less sludge will be created.

Another approach is dissolved air flotation (DAF). A sampling program should be conducted to characterize the oil and grease. If the oil and grease are readily floatable, the API/CPI system is all that is needed. If the oil and grease are emulsified, DAF with a chemical addition should be used to break the emulsion. Polymer can sometimes break emulsions, with the advantage that less chemical sludge is produced.

- Several membrane separation systems would be appropriate for the Anniston Army Depot. The first system is ultrafiltration (UF) of the steam cleaning waste stream. If the oil and grease in the waste is soluble or emulsified, a UF treatment system could remove enough oil and grease to make excess lime addition at the IWTP unnecessary and avoid producing the additional sludge associated with the addition of lime. The UF system should be pilot tested after performing a waste characterization study that focuses on the specific fractions of oil and grease (soluble, emulsified, suspended, and floatable). UF technology has been used to treat oil wastes from facilities using steam cleaning.

The second membrane separation process would focus on suspended solids removal from the IWTP effluent. Currently lime is used to precipitate metals and to produce a low turbidity effluent. The lime dose necessary to produce a low turbidity effluent produces large quantities of sludge. Sodium hydroxide has been used instead of lime to raise the wastewater pH; although sodium hydroxide produces less sludge, it does not produce a low turbidity effluent. The objective of this second study will be twofold: to determine the limitations of using sodium hydroxide in terms of effluent quality (i.e., soluble metal concentration) and the associated benefit of reduced sludge production, and to determine if microfiltration can be used as a polishing step to enhance solids capture.

Because the sludges generated from treating the cyanide and chromium waste streams and the general waste stream at the IWTP are hazardous by definition (EPA F006 wastes), switching from lime to sodium hydroxide for pH adjustment may reduce operating costs. Lime is much less costly than sodium hydroxide on a per pound basis, but excess lime is used to produce a low turbidity effluent. Sodium hydroxide will produce significantly less sludge for disposal, but it must be followed by an effluent filtration step to ensure compliance with the facility's discharge permit. An economic analysis should be performed to determine if the substitution of sodium hydroxide and effluent filtration are cost effective. The chemical substitution may be a way to comply with the Army's goal of hazardous waste reduction. If necessary, ultrafiltration and nanofiltration would be pilot tested.

The Anniston Army Depot's current NPDES permit does not appear to be based on water quality standards. When the permit is renewed in 1996, metal limits may be imposed, and enhanced metals removal at the IWTP may become necessary. Microfiltration of the IWTP effluent has the potential to provide enhanced solids capture and produce a better quality effluent. Microfilters with a rated pore opening of 0.1 to 0.2  $\mu$  will remove soluble metals. (The USEPA defines soluble metals as anything that passes through a 0.45  $\mu$  filter.) Therefore, the filtrate from the microfiltration will be of a much higher quality than from a conventional sand filter. If necessary, ultrafiltration and nanofiltration would be tested.

- Electrochemical precipitation could be used instead of lime to remove chromium. Such a system lends itself well to automation, which would ensure compliance with environmental regulations. Depot personnel indicated that the sludge generated by the existing system is not considered hazardous. The processes upstream of treatment facilities should be examined to determine whether a contaminant load can be reduced using countercurrent rinses, water conservation,

and recovery and reuse of rinse waters. Work completed by the DOE at Oak Ridge and by membrane manufacturers indicates that this might be a viable option.

- The Anniston Army Depot should explore delisting of its IWTP sludge. Lime sludge often can pass the TCLP analysis. If the sludge passes TCLP, the USEPA may be willing to delist the sludge. The petition to delist may have to be preceded by a pollution prevention effort aimed at reducing the mass of metals discharged in the waste stream. The USEPA has defined the sludge from treating metal finishing wastes as hazardous. One key factor this facility will have to prove is that their raw waste has different characteristics from those the USEPA evaluated to formulate its policy; and, because this waste is different and passes TCLP, it should be delisted. The USEPA will have to be consulted to define the protocol to be followed.

### ***Tobyhanna Army Depot***

The Tobyhanna Army Depot has received its new NPDES permit, which has limits based on water quality standards. This new permit (Table 3) includes strict limits on metals and nutrients and will require modifications to the sanitary, and possibly industrial, wastewater treatment plants. Some of the issues are interrelated, and possible long-term solutions must be examined in detail to ensure that the most economical, practical solution is found.

- The trickling filter facility can be upgraded for biological removal of nitrogen. A feasibility study should be conducted to determine the modifications needed to effect nitrification and denitrification.

The second problem associated with the new NPDES permit limits is metals removal. The concentrations of metals allowed by the NPDES permit are extremely low. The sanitary waste treatment plant already uses effluent filtration for enhanced solids removal. Two basic methods of metals removal are possible: alkaline precipitation and stoichiometric precipitation. For alkaline precipitation, the wastewater pH would have to be raised to between 8.5 and 10.5. A tertiary treatment clarifier and a filter also would be needed, and provisions to control the pH of the treated effluent would be necessary.

- Stoichiometric precipitation, which is probably more cost effective than conventional precipitation, consists of sulfide or electrochemical precipitation. It differs from alkaline precipitation in that the chemicals are added in a stoichiometric ratio to the metals present rather than by pH adjustment alone.

Stoichiometric precipitation usually produces less sludge than alkaline precipitation, and the sludge may be able to pass TCLP. Provisions for either sulfide or electrochemical precipitation can be added to the existing sanitary wastewater treatment plant, possibly without extensive or costly process additions. The overall cost will depend on whether the existing traveling bridge filters can retain enough precipitated metal floc to meet permit limits. If they cannot, a more efficient and expensive filter system should be evaluated.

- The potable water supply for this facility contains elevated concentrations of cadmium, copper, and lead. A mass balance must be performed to determine whether the metals in the water supply are causing the elevated metals concentrations at the sanitary wastewater treatment plant. If so, it may be more cost effective to treat the drinking water than to treat the metals at the wastewater treatment plant. The water supply also should be assessed for corrosivity. Alkalinity or pH adjustment to reduce corrosivity will prevent copper, lead, and zinc from being dissolved from pipes or plumbing fixtures. According to the new NPDES permit, it does not matter where the metals come from; but, once in the water, they must be removed.
- Counter-current rinsing metal plating rinse water and improved dragout control should be evaluated. The use of high purity water also should be evaluated to replace potable water. Potable water contains dissolved salts that accumulate in the bath. High purity water contains lower concentrations of dissolved solids and will extend bath life. These approaches will reduce the amount of metal-bearing waste for treatment.
- Ultrafiltration of steam cleaning wastewater would reduce oil and grease discharged to the IWTP, which would improve IWTP process performance. Another method of oil and grease removal is cold vapor evaporation. Cold vapor evaporation could be used to concentrate metals and oil and grease in the wastewater from Building 9.
- The facility has to meet an extremely low silver discharge limit. The currently used silver recovery units are ineffective. Alternative methods to reclaim and recover silver before it reaches the waste stream should be evaluated.
- Environmentally sound methods should be established requiring purchasing departments to use only materials that can be disposed of in an environmentally safe manner. A database would be established to assist not only environmental control personnel but also purchasing agents. Chemical analysis of materials will be used to determine if they can be disposed of to wastewater.

**Watervliet Arsenal**

- The potential of induced solar heating for sludge dewatering should be evaluated. Such a system would include transparent covers for all sludge drying beds for weather protection and temperature control.
- The boiler system of the Watervliet Arsenal produces excess steam; therefore, the use of steam to dry sludge should be evaluated.
- Microfiltration should be evaluated as a means of reducing alum use. This would be done conditionally, as the sludge is currently delisted. Watervliet Arsenal has demonstrated the feasibility of recycling by cutting fluid using ultrafiltration. The installation of a cutting fluid recycling system is planned as a joint effort between Watervliet Arsenal and USACERL. The use of ultrafiltration rather than the addition of alum should be evaluated to remove oil and grease to reduce the amount of solid waste produced. The oily waste can be incinerated.
- An evaluation should be conducted to determine whether the sludge with high chromium concentration has any economic uses.
- An evaporator should be evaluated to increase the concentrations of phosphoric and sulfuric solutions in the plating bath. The acid solution absorbs moisture from the air. Currently acid solution is wasted, with fresh acid added to increase the acid concentration in the bath. Using the evaporator would result in direct savings in treatment costs and extension of the life of the bath. Its use also will reduce the volume of RCRA waste generated at the site.
- The use of polymer as a substitute for the addition of alum should be evaluated. Polymers can perform the same function as alum without significantly increasing sludge production.
- Studies have indicated that 50 to 100 percent of the alum used in traditional water treatment can be recovered through acidification. This recovery could reduce the amount of sludge produced by approximately 30 percent. Bench scale studies should be conducted to determine if the alum recovery is viable, considering the large quantity of chromium in the sludge.

## 6 Recommendations

This report summarizes the results of field visits conducted to evaluate the Army's current industrial sludge management technologies. Recommendations are provided regarding short-term and long-term improvements to provide the Army more effective management strategies.

Areas of future improvement and research for sludge management at AMC facilities include the following.

### Plating Research

A general research program to upgrade/modernize plating operations at AMC facilities is needed. Both production techniques and environmental compliance should be evaluated. New plating techniques, such as ion vapor deposition, should be evaluated as replacements to existing technologies. Existing technologies should be evaluated for the possibility of material recovery/recycling. Microfiltration, ultrafiltration, nanofiltration, reverse osmosis, and electrodialysis should be considered as methods to concentrate rinse waters for recycle back into the plating bath. This research should be carried out jointly with the plating operating staff at the various AMC facilities and facility environmental compliance staff. The Army plating shops produce a quality product, and product quality must be maintained. The research must consider all aspects of the plating operations: water pollution, recycling, operator attention, air emissions, product quality, production rates, etc.

### Steam Cleaning Wastewater

AMC personnel interviewed during site visits indicated difficulty in the treatment of steam cleaning wastewater because of the quantity of oil and grease in the waste stream. Steam cleaning wastewater currently is treated using either alum or lime, which absorb oil and make a floc particle that is heavy enough to settle. Technologies such as API/CPI oil/water separators need to be evaluated to remove and recycle oil. Recovered oil can be used as a waste energy source if the facility has an existing waste

incinerator. The quantity of chemical used will be reduced by removing free floatable oil ahead of the IWTP.

Another approach for the treatment of steam cleaning wastewater is DAF. A DAF uses super-saturated water to increase the removal of floatable particles. DAFs have been used by several different types of industries to remove large quantities of oil and grease.

A bench scale pilot test program should be conducted to characterize the oil and grease. If the oil and grease is readily floatable, the API/CPI system should be used. If the oil and grease is emulsified, DAFs should be used with chemical addition to break the emulsion. Polymers sometimes can be used to break emulsions, and the advantage of using polymers is that no chemical sludge will be produced.

## **Membrane Separation Systems**

Several different membrane separation systems can be pilot tested and installed. UF can be used to treat the steam cleaning wastewater. This type of treatment process is particularly successful if the oil and grease in the steam cleaning wastewater is soluble or emulsified. A UF treatment system could remove enough oil and grease to avoid excess chemical addition and sludge generation at the IWTP. Different UF systems could be pilot tested after performing a waste characterization study that focuses on the specific fractions of oil and grease (soluble, emulsified, suspended, and floatable). UF technology has been used to treat oil wastes from facilities using steam cleaning. Different types of UF membranes could be evaluated with actual wastewater from a few AMC installations to determine removal efficiencies and operational characteristics.

Another membrane separation project would focus on suspended solids removal from the IWTP effluent. Various chemicals currently are used at the AMC facilities visited to precipitate metals and to produce a good, low turbidity effluent. The chemical dose necessary to produce a low turbidity effluent generally produces large quantities of sludge. Sodium hydroxide has been used instead of lime to raise the wastewater pH and remove metals because it produces less sludge. The disadvantage of using sodium hydroxide is that it does not produce a low turbidity effluent. The objectives of the latter project would be: to determine the limitations of using sodium hydroxide in terms of effluent quality (i.e., soluble metal concentration and the associated benefit of reduced sludge production); to determine if microfiltration can be used as a polishing step to enhance solids capture to produce a low turbidity, high quality effluent (lower

metals concentration); and to evaluate the use of ultrafiltration and nanofiltration and to develop pretreatment methods.

### **Electrochemical Precipitation of Metals**

Electrochemical precipitation can be used to remove chromium or other metals instead of lime. The advantages this type of treatment can offer AMC facilities are that the system lends itself easily to automation and the sludge generated by this treatment system may not be considered hazardous.



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## Abbreviations/Acronyms

AMC	Army Materiel Command
AOP	advanced oxidation process
API	American Petroleum Institute
BAT	best available technology
BOD <sub>5</sub>	5-day biochemical oxygen demand
BTEX	benzene, toluene, ethyl benzene, and xylene
C	Celsius
CEM	combined effects munitions
CFR	Code of Federal Regulations
COD	chemical oxygen demand
cu ft	cubic feet
DA	Department of the Army
DAF	dissolved air floatation
DE	diatomaceous earth
DOD	Department of Defense
DOE	Department of Energy
DRMO	
EMR	electrolytic metal recovery
ESTP	East Area Treatment Plant
F	Fahrenheit
FOG	Fats, oils, and grease
ft	feet
GAC	granular activated carbon
gal	gallon

gpd	gallons per day
gpcd	gallons per capita per day
gpm	gallons per minute
GEAE	General Electric Aircraft Engines
HAZMIN	hazardous material information network
hp	horsepower
in.	inch
ISP	insoluble sulfide process
IWTP	industrial wastewater treatment plant
KAAP	Kansas Army Ammunition Plant
kWh	kilowatthours
LAP	load, assemble, pack
lb	pound
mg/L	milligrams per liter
mgd	million gallons per day
mm	millimeter
μ	micron
μm	micrometer
NPDES	National Pollutant Discharge Elimination System
O&G	oil and grease
O&M	Operations and Maintenance
ORP	oxidation reduction potential
OSHA	Occupational Safety and Health Administration
ppd	pounds per day
ppcd	pounds per capita per day
ppm	parts per million
POTW	publicly owned treatment works
psi	pounds per square inch
psig	pounds per square inch ?

QA/QC	quality assurance/quality control
RCRA	Resource Conservation and Recovery Act
R&D	research and development
SARA	Superfund Amendments and Reauthorization Act
scfm	standard cubic feet per minute
SPDES	State Pollutant Discharge Elimination System
sq ft	square feet
SWD	sidewater depth
SSP	soluble sulfide process
TCLP	toxicity characteristic leaching procedure
TDS	total dissolved solids
TNT	Trinitrotoluene
TSS	total suspended solids
TTO	total toxic organics
UF	ultrafiltration
USACERL	U.S. Army Construction Engineering Research Laboratories
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compounds
WREFS	Waste reduction evaluations at Federal sites
WWTP	Waste water treatment plant

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